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STUDY OF U.S. SHIPBUILDING CAPACITY AND REQUIREMENTS

BY

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1.) Introduction.

The U.S. shipbuilding industry which developed a capacity second to none during World War II, has since been subjected to a continual decline in the volume of ship construction. Although the dollar volume of order has recently increased appreciably, the tonnage and number of ships built or ordered has remained small. In particular, the industry has been unable to participate in the world wide increase in ship construction currently growing at an unprecendented rate, both with regards to the number and size of ships built. The volume of ships constructed abroad has led to the adoption ofmany aspects of modern mass production principles resulting in major gains in both productivity and cost.

The private shipbuilding industry of the country is probably more dependent on government decisions than any other industry in this country. Over 80% of its dollar volume is derived from Navy shipbuilding work with another 18% supported by subsidies. This factor has until the mostrecent past greatly contributed to the low measure of incentive prevailing in the industry subject to the changing whims of the Administration and Legislature. While it is commonly assumed that the industry is not "competitive" as a result of large labor cost differentials compared to foreign yards, it should be noted that higher labor costs are just one of many reasons for less than achieveable effectiveness of this basic industry. The unpredictability of the market and other conditions have resulted in insufficient capital investment forimprovement and upkeep, uncoordinated management, ineffective plant and manpower utilization, lack of planning and production engineering, and in general a rather indifferent outlook, all of which contribute to the lack of productivity. The term productivity is obviously subject to discussion and various definitions can be given to a measure representing useful product output per man-hour or unit cost. The particular definition will always depend on the reviewer. Management, for instance, may be more interested in return on capital than productivity measured in output. It is the purpose of this study to discuss among others some of the requirements for increased ship manufacturing productivity. In order to accomplish improvements, an integrated effort must be made to utilize the multitude of modern production, material handling, control, management, and labor effectiveness method. Only if and when ship production is transformed into a well balanced and planned production process will substantial improvement occur.

2) Requirements For Modern Ship Production

One of the major drawbacks of current U.S. shipbuilding practice is the large variation of labor intensity throughout many yards which results in extremely low productivity in some areas, intermittent production flow, and a large wastage of manhours and investment in coordinating the flow of people, materials, and work pieces. It can easily be shown that U.S. shipbuilding has one of the lowest proportions of useful productive work as a function of manhours paid of any major U.S. industry. Other industries have improved their productivity by mass production techniques or methods whereby the work pieces flow by the worker who has all tools and materials required for the performance of his function at his fingertips and can, therefore, devote himself fully to the accomplishment of his task.

Outfitting, which has long been ignored, is of particular importance in the development of effective shipyard processes. It should be recognized that automated steel fabrication and assembly processes constitute but a small portion of the total shipbuilding effort. On the other hand, outfitting of the assembled hull after completion or erection results in a large amount of labor intensive activities in extremely small spaces with resulting low labor productivity. A prime objective must therefore be an evaluation of the potential of diverting outfitting to a large number of different areas in the shipyard and to sequential stages in the actual hull erection process.

Of prime importance to the effective use of a ship production facility is the genreal layout, with particular reference to the ship erection line, subassembly transfer method and, finally, launching techniques. Shipbuilding is a very complex production process with large deviations from the expected completion times for the various individual production states. As a result, it is imperative that sufficient storage or buffer areas as well as production resources be provided at each nodal point.

It is only recently that interest in the evaluation and development of new ship production processes has been generated and, as a result, mostof this recent work has been devoted to an analysis of potential solutions. The most important conclusion reached so far is the requirement of integrating the operational and production needs into the ship design. Conventionally, ships have been designed without proper consideration of the production requirements which generally lead to costly ship construction.

Another important consideration isthe adoption of in-line production techniques to the construction of ships. Although some of these techniques developed in the automobile and aerospace industry have been incorporated into the steel fabrication processes of many U.S. shipyards in recent years, very little advantage has been taken of in-line production techniques in other shops and, in particular, in the steel and ship erection processes. Thecapabilities of numerical control for the various production processes and the availability of accurante measurement and alignment techniques permit the consideration processes. An ever present and important factor in the layout of a new ship production facility or the redesign of an existing facility is the introduction of sufficient buffer storage areas to assure maintenance of continuous process flow and material control.

An important aspect in shipyard design and ship production planning isproper documentation, the availability of a data bank, and an efficient information and data control system. These are required for the planning and scheduling of the ship production process and are of particular importance in series construction of ships. Planning and scheduling of the production andmaterial flow and the allocation of human and other shipyard resources requires the use of recently developed network analysis techniques. The adaptation of computerized PERT and critical path networks, as well as the use of flow graph techniques, has been found attractive. These methods of information and process modeling can usually be tied to optimization techniques such as linear, dynamic, or parametric programming designed to develop the best plan and schedule to minimize resource application or maximize resource utilization within a given schedule. The extent and complexity of process and material flow in a ship production facility often makes the network approach cumbersome. By proper subprogramming, using buffer storage areas a nodal points, such networks can often be greatly reduced, or subdivided into reasonable size.

The results of several network analyses of ship production processes indicate the advisability of central material storage for all material except processed steel. Received and processed material is accumulated in one central area and formed into integrated kits on steel pallets designed to centralize all the material required for erection in one specific area or space. Such a procedure not only assures proper material flow control, but also more precise planning.

These kits include everything required for the assembly of a particular subsystem, even such items as specialized hand tools and consumable material.

Listing and transfer problems in a modern ship production facility impose new and exciting problems as a result of the potential size of the prefabricated units to be handled. Detailed analysis has to be applied to the design and planning of the material handling equipment of a modern shipyard facility to assure effectiveness.

Developed structural optimization programs permit trade analysis of steel subassemblies in which construction and handling costs are traded off, introducing such factors as erection costs, measurement costs, and alignment costs. As a result of these analyses, it can often be shown that subassemblies or modules weighing several thousand tons can be considered in a modern shipyard facility. The acceptable tolerances in the steel fabrication process and erection area permit the handling of such a large section without the requirement for major corrective action in the final ship assembly.

Statistical methods have been developed for the analysis of tolerance buildup resulting from fabrication and erection inaccuracies. These analyses are also concerned with the development of an optimum correction procedure when applicable and uses a cost effectiveness approach in the tradeoff of many manufacturing techniques, unit size, measurement techniques, alignment methods, and the final corrective action. The results of some initial analyses indicate that the additional expense involved in introducing a higher degree of accuracy in the shop fabrication and subassembly processes is well warranted.

An additional area of interest is information transfer. Here we are concerned with the development of a procedure which will permit better control of individual worker's functions. As a result, we are studying the use of numbered isometric sketches showing detailed erection or fabrication sequences which will be used by individual workers. It is believed that such sequence diagrams and isometrics can eventually be generated by the ship working plan design programs currently being developed.

Other areas in which operations research techniques are used are ship production engineering, market analysis and development of shipyard criteria for the suboptimization of resource allocation. Some of these programs are concerned with the optimization of inventory and procurement policies as well as with the physical layout for material storage and maintenance. Similarly, maintenance and support service procedures generally benefit by the application of analysis methods. Some of the operations analysis techniques are also useful in the formulation of cost centers and cost control. These form part of an integrated management information system which is a basic prerequisite for an effective shipyard management and control structure.

An analysis has also been found useful in the development of effective outfitting policies concerned with the planning of the degree of modularization and proper assembly of outfitting the items. In this connection the relative advantage of centralized outfitting functions is of major importance as it can easily be shown that a high concentration of manpower application normally results in reduced productivity.

Our efforts for improving ship production techniques must be aimed at curing the inherent ills of our ship construction approach and not isolated symptoms such as steel marking, cutting, or storage. This requires extensive analysis, planning, and coordinated management and control ofmaterial flow, fabrication processes, manpower allocation, resource allocation, and inspection. The isolated improvements made by the many shipyards in which a limited number of new techniques or processes are utilized to the exclusion ofothers without consideration of their overall effects or the resulting flow balance has often achieved only marginal improvements at a cost/incremental effectiveness ratio that would be considered unreasonable by other industries.

A prerequisite for progress is better coordination and collaboration among the various interests in ship construction and the dissemination of the large amount of data and information available in the various shipyards. We hope that the shipbuilding industry of this country will join in facilitating this effort by permitting the exchange of experience and information for the good of all members of the industry and the nation as a whole.

The rationale governing the design of a modern ship production facility depends on defined objectives and imposed constrains. The objectives can normally be stated in terms of performance criteria which must be economic to be meaningful. These performance measures have to be translated into productivity terms on an overall facility and individual shop, assembly area, or even work center basis. The farther down the line, the farther the performance measure will be from the stated facility criteria. Yet it is important to maintain the economic aspects of performance measures or indexes to the lowest level. Some of the basic requirements for an effective modern ship production facility are:

1) Growth Potential and Adaptability.

2) Least Cost Mix of Labor and Capital.

3) High Utilization of Productive Capital Investment.

4) Minimization of Supporting Nonproductive Capital Investment.

5) Effective Decentralization of Labor Intensive Activities.

6) Provision of Sufficient and Properly Planned Storage, Marshalling and Buffer Areas.

7) Flexible Yet Extensive and Expandable Material Handling Equipment.

8) Effective Continuous and Controlled Material Flow Processes.

9) Provision for Efficient and Accurate Measurement and Alignment Techniques, and Effective Information Feedback.

10) Introduction of Preassembly of Outfitting Items and their fitting into Assemblies before the Final Erection of the Ship.

11) Optimization ofPanel, Subassembly and Assembly Unit Sizes.

12) Effective design of the various shop fabrication processes to feed the assembly area with themaximum utilization of the capital investment in the shop and a minimum requirement for in-process storage.

13) Effective information transfer for the various fabrication and erection for assembly processes.

14) Efficient material, production and information flow control.

15) Integration of material kits.

16) Maximization of repetitive work functions and development of work procedures requiring a minimum of skill.

17) Scheduled and reserve capacity.

The above and several other considerations are basic requirements for the effective development of an efficient ship production facility. They are not mutually exclusive and also include some conflicts when translated into facility design criteria.

The design of an effective ship production facility requires full integration of shipyard processes and control. This in turn imposes coordination of production, material and information flow. Each of these flow elements interacts with the others and is affected by the shipyard criteria developed on the basis of the facility objective and the constraints imposed on ship production as a result of market potential, enviroment, physical phenomena, labor availability, costs of material, utilities and services, cost of capital, and many qualitative factors. Many shipyards have in thepast been constructed or located to satisfy political, military or other "strategic" purposes, such as the industrial use of peak capacity of steel mills. Access and transportation cost affect a shipyard more than most other heavy industries. However, a shipyard can seldom afford to be effectively located at the hub of a large. high intensity industrial area due to its history of highly fluctuating labor andmaterial demands. The very magnitude of the individual product of the shipyard is a major obstacle to balanced production, resource utilization, and effective control. In a conventional shipyard, the labor requirements for the construction of a ship vary by a factor or 5 from start to completion, with the manpower loading skewed towards the last third of the construction period. Even with proper scheduling, it it can easily be shown that manpower requirements in a conventional shipyard can deviate by over 20% overtime for a year with a full order book and four to six ship deliveries per year. To maintain some semblance of level employment, many conventional yards resort to makework or subsidiary activities which seldom pay off. The Japanese have shown that a more uniform manpower loading can be achieved by pre-outfitting, shop assembly, block construction, and integrated management and control.

Efficient shipyard production flow design is further handicapped by the lack of extensive repetitive operations. Production automation has, in the past, been synonymous with mass production of identical parts. Many available automation techniques have not been compatible with the particular production problems of shipbuilding. Recent developments in multi-purpose, numerically controlled machines, capable of producing nonrepetitive parts, requiring similar operations, permit a re-evaluation of a multitude of production processes in ship construction to assure more continuous and balanced production flow. A basic difficulty is introduced by the size of individual parts and subassemblies which require handling, alignment, measurement and fabrication. Therefore, analysis must also include a tradeoff of machine versus part mobility. These and other considerations will affect the type of control and sequencing devices imposed on the process.

All the elements of Ship Production are an integral part in shipyard design. However, a major problem in shipyard design is the establishment of economic opportunity which is effected by the following:

a. Unpredictability of market

b. Large proportion of material cost in total cost

c. Technological progress

d. Large investment requirements as a function ofpotential sales

e. Large labor requirement fluctuation during construction of one ship

f. Special labor skill requirements

g. Rapid building up of unit size

h. Inflexibility of location

i. High material transport costs

j. Large material inventory requirements

k. Large operating capital needs

l. Local political and economic factors

m. Labor union and work rules

n. Inspection and regulator body requirements

o. Limited market

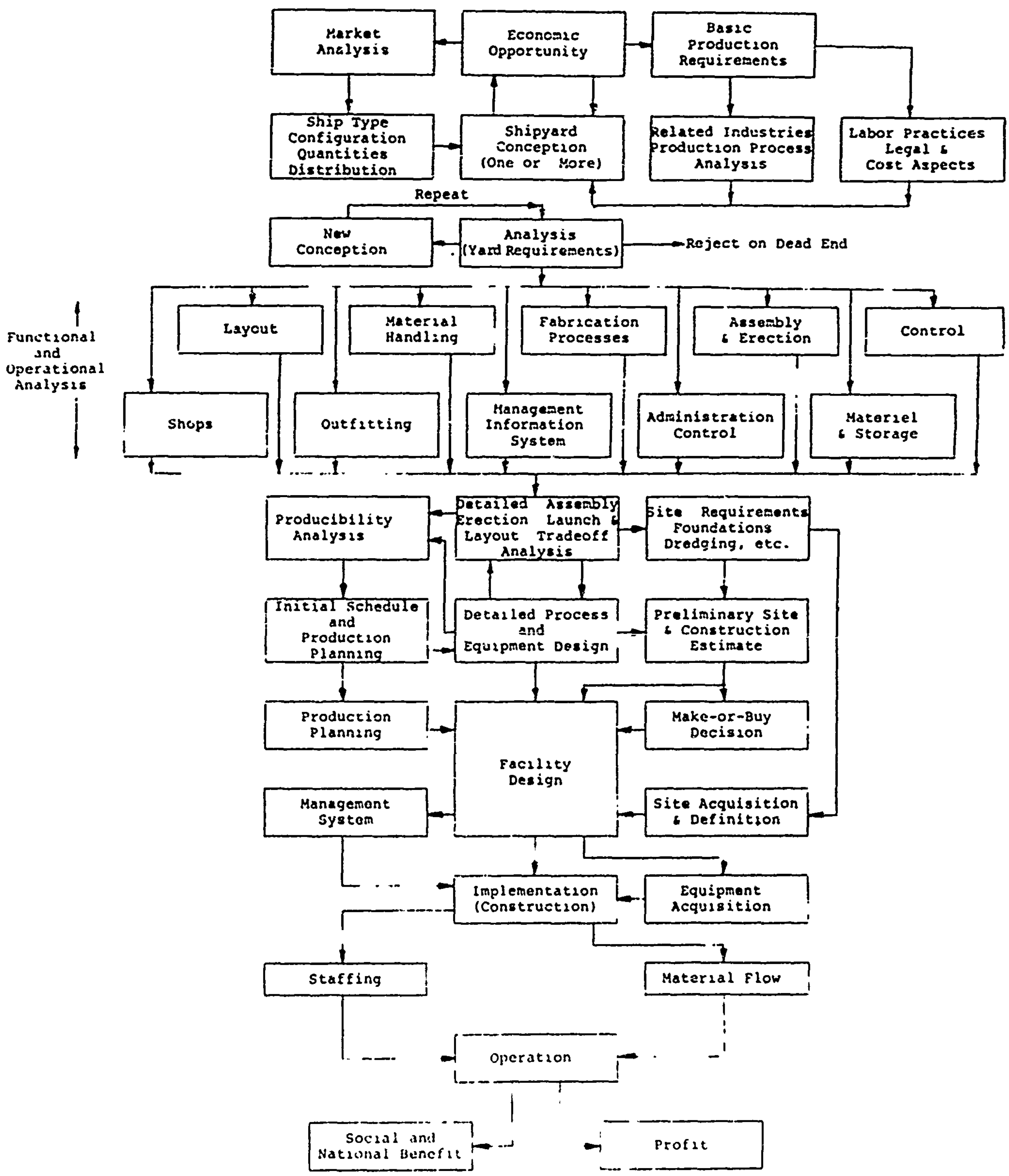
p. National defence aspects

q. Inflexibility of production flow

r. Long material, facility andmachinery lead times

s. Large in-yard differences in labor intensity

Once the economic opportunity is established and the basic ship production requirements set, the shipyard engineering design process commences as presented in a simplified manner in Figure 2-1.



SHIP ENGINEERING DESIGN PROCESS

Fig. 2-1

Ship production consists of a large variety of processes with various response times, which implies the time between inputs and outputs from various fabrication, assembly, and erection processes. While some processes are practically continuous, others are extremely intermittent. It is found that shipyard proce-s design has to be structured around the most intermittentprocesses. We, therefore, commence our analysis by evaluating the large erection and assembly requirements, their relative costs, labor intensity, and effects on shipyard layout and material flow. The size and extent of assembly and outfitting at the various stages is studied in detail, and time, weight, cost, and connection requirements are established for each assembly. Assembly is then perturbed about the assumed starting point and various combinations of subassemblies in the larger units, both in the ship erection as well as in the assembly of subsystems, introduced. Once the most effective pattern of subassembly, assembly, and erection is developed, various layout configurations for the yard are conceptualized. These layouts are then evaluated with respect to possible means of subassembly or assembly support and transfer as well as the erection platform and launching techniques for the completed ship. Simultaneously, we develop effective superstructure assembly methods which fit the schedule and transfer requirements of the main hull. Finally, the various shop facilities surrounding the subassembly, assembly, and erection areas are developed based on logical flow configuration and on fabricated material flow requirements. Themost important factor is the definitive establishment of the time interval between material flow requirements to the various assembly areas with the resulting need for extensive buffer storage between the various shops which generate more continuous flow of materials and small prefabricated units than can be accepted by the various assembly activities. As a result, we develop optimum sizes for prefabrication of hull steel, and other shop assemblies which would permit a proper assimilation of related parts in the buffer storage area. The buffer storage is designed to permit a proper assimilation of related parts in the buffer storage area. The buffer storage is designed to permit the assembly of palletized kits consisting of the output of a variety of shops and material storage facilities and designed to provide complete and self-contained processed and unprocessed material assembly for a specific stage in the assembly activity. These kits are designed to be accumulated on steel pallets where possible, and to include, when necessary, required tools and consumable material.

Material handling equipment is designed to assure maximum utilizatination and flexibility of use. As a result, a large variety of unconstraint mobile, as well as track constraint material handling equipment, should be considered and designed to not only effectively handle the specific material transfer requirements, but also permit its use for alignment, and erection support during the assembly processes. Detailed time and motion studies of the various material handling needs should be simulated to develop the required distribution of material handling equipment. Various support and transfer devices which may be considered in the design and layout of the ship production facility are listed in Table 2-1. Some of these devices serve not only for transfer, but also to support material and assemblies during production or erection. As a result, detailed cost tradeoff studies have to be made to support the choice of equipment. An additional factor in an analysis is provision for redundancy and growth. Availability studies and maintainability evaluations are made with particular reference to the requirement of simultaneous usage of material handling equipment and the obtainment of service and support facilities.

The overriding criterion in the facility design must be to develop a balanced layout and system with resulting high utilization of capital investment. This approach also affects the selection and design of the final erection support and the launching method. As will be noted by any student of shipyard practices throughout the world, graving docks appear to be the preferred erection and launching method for modern automated shipyards. Large graving docks provide a excellent and well integrated erection and launch platform for effective andsafe erection and launch. On the other hand, it requires lift-in of all assemblies and materials and concentration of a large amount of work functions in a very confined space which, furthermore, is below the level of the rest of the yard, with the resulting effect on environment and facility for providing support for the workers. Other erection and launching techniques may be more flexible.

TABLE 2.1

SUPPORT & TRANSFER DEVICES

PALLETS - CLOSED - OPEN

LOWBOYS - STEERABLE - SELFLOADING

SPECIAL PICKUP - POSITIONING DEVICES

CRANES - TURNTABLES - STEERABILITY

GOLIATH CRANES

AIR CUSHION PALLET TRANSFER

FLUID CUSHION PALLET TRANSFER

CANAL AND LOCK SYSTEM

FLUID PALLET SUPPORT - REMOVABLE WALL

SLIDING PALLET TRANSFER (Flourogold Teflon Lubricated Steel)

ROLLER SUPPORT SYSTEMS

CONVEYOR SYSTEM (ROLLER-BAND)

RUBBER WHEEL PALLET SUPPORT

MOBILE CRANES

DESIGN CONSIDERATIONS

STABILITY REQUIREMENTS

TRANSFER POWER REQUIREMENTS

ADJUSTMENT SENSITIVITY

SUPPORT ELASTICITY (WIRE, PALLET ETC.)

As a result, various layouts must be developed for stationary ship erection on thelaunch platform (graving dock, ways, sidelaunch, inclinator, etc.) and for an in-line production and erection process in which the launch platform is not used for assembly and erection.

The most important consideration in modern shipyard design is the introduction of continuous in-line production processes with integrated material, information, production, assembly, and erection flow. This, in turn, imposes requirements of in-line measurement, tolerance control, correction, alignment and inspection.

The adoption of in-line production techniques similar to those which were developed in the automobile and aerospace industries, have to date only been accomplished in the steel fabrication processes of shipyards. However, very little advantage has been taken of such techniques in other shipyard shops and in particular, in the ship erection process.

Ship production or fabrication is a typical link-node flow process. To maintain the semblance of a continuous process flow for the ship erection process, thelayout of a new ship production facility, or the redesign of an existing facility, must have sufficient buffer storage areas. These are required to overcome the inherent delays or deviations found in such typical link-node flow processes.

Much work has recently been devoted to the statistical and real time simulation of ship production processes and the establishment of buffer storage area requirements to assure maximum utilization of invested capital equipment.

The results of several network analyses of the ship production processes indicate the advisability of central material storage points for all material. Received and processed material is accumulated at the nodal points of the flow sequence, and formed into integrated packages which are designed to centralize all the material required for erection in one specific area or space. Such a procedure not only assures proper material flow control, but also enables more precise planning. These kits include everything required for the assembly of a particular subsystem, even such items as specialized hand tools and consumable material.

To compare various layouts in which shops are only diagramatically defined, a preliminary manloading and throughput analysis is required for the assembly of a particular subsystem, even such items as specialized hand tools and consumable material.

To compare various layouts in which shops are only diagramatically defined, a preliminary manloading and throughput analysis is required to develop a first cut estimate of the sum of annual expected capital and labor charges over productivity in potential ship production sales. This task, though complex and time-consuming, can be effectively accompished if each considered layout is backed by:

1) Functional Flow Diagrams.
2) Operational Flow Diagrams.
3) Material Flow Diagrams.
4) Production Flow Diagrams.
5) Manloading Charts.

Control and information flow need not be imposed at this state in the design although it will be found to affect the productivity and throughput.

2.1 Ship Production Management Information Systems

The added value of direct labor in ship production in the United States is among the lowest, percentage wise of any major U.S. production process, resulting in a large proportion of the final value of the product comprised of material supplies. Effective material handling, material storage, material preservation, material usage, and material flow are important requirements for an effective shipyard operation. Similarly, the large number of diverse skills and the large dispersion of manpower in shipyards requires more sophisticated controls on labor allocation than in many other heavy industries. Furthermore, the capital investment in shipyards is normally a larger proportion of added value to annual sales than in many other industries and, therefore, optimum utilization of capital equipment becomes a prerequisite of effective shipyard operations.

To provide effective planning, scheduling, and allocation of resources in a shipyard, a vast amount of data must be recorded, listed, and transmitted to permit the various levels of management to effect the required supervision and control. From shipyard to shipyard, organizations are structured quite differently depending on management philosophy. Even the definition ofwork, material andcost centers varies widely from yard to yard. To normalize comparisons between yards it is essential that an effective shipyard management system is concerned with the following types of data:

1) Material inventory status
2) Material-in-flow reports

Table 2.2

Labor Allocation
(High Class Cargo Ship)

	Labor % Automated Yard	Labor % Conventional Yard
Steel Fabrication	3	4
Panel and Shell	4	6
Outfitting:		
Electrical	4	4
Pipe	2	3
Machinery	4	5
Other	5	5
Subassembly	22	11
Module Assembly	31	--
Ship Erection	14	30
Launch	1	1
Post Launch Outfit	10	31
	100%	100%
Total MH	68%	100%
Time Required	54%	100%

In addition to manpower savings, we obtain higher facility utilization (more throughput) and less material in process, resulting in higher return on investment capital.

3) Material demand by various fabrication and erection work centers

4) Material on order

5) Utilization of the various fabricating machinery

6) Utilization of the various mobile and installed material handling equipment

7) Status of the various work in process in shops

8) Status of the various subassembly anderection processes

9) Status of distributed system prefabrication

10) Status of outfitting in various subassemblies

11) Progress reports of outfitting during ship erection

12) Ship completion reports

13) Launching readiness reports

14) Outfitting after launch reports

15) Labor utilization andrequirements reports

16) Support services requirements and use

17) Buffer storage utilization

18) Assembly kits completion and status

19) Utility consumption reports

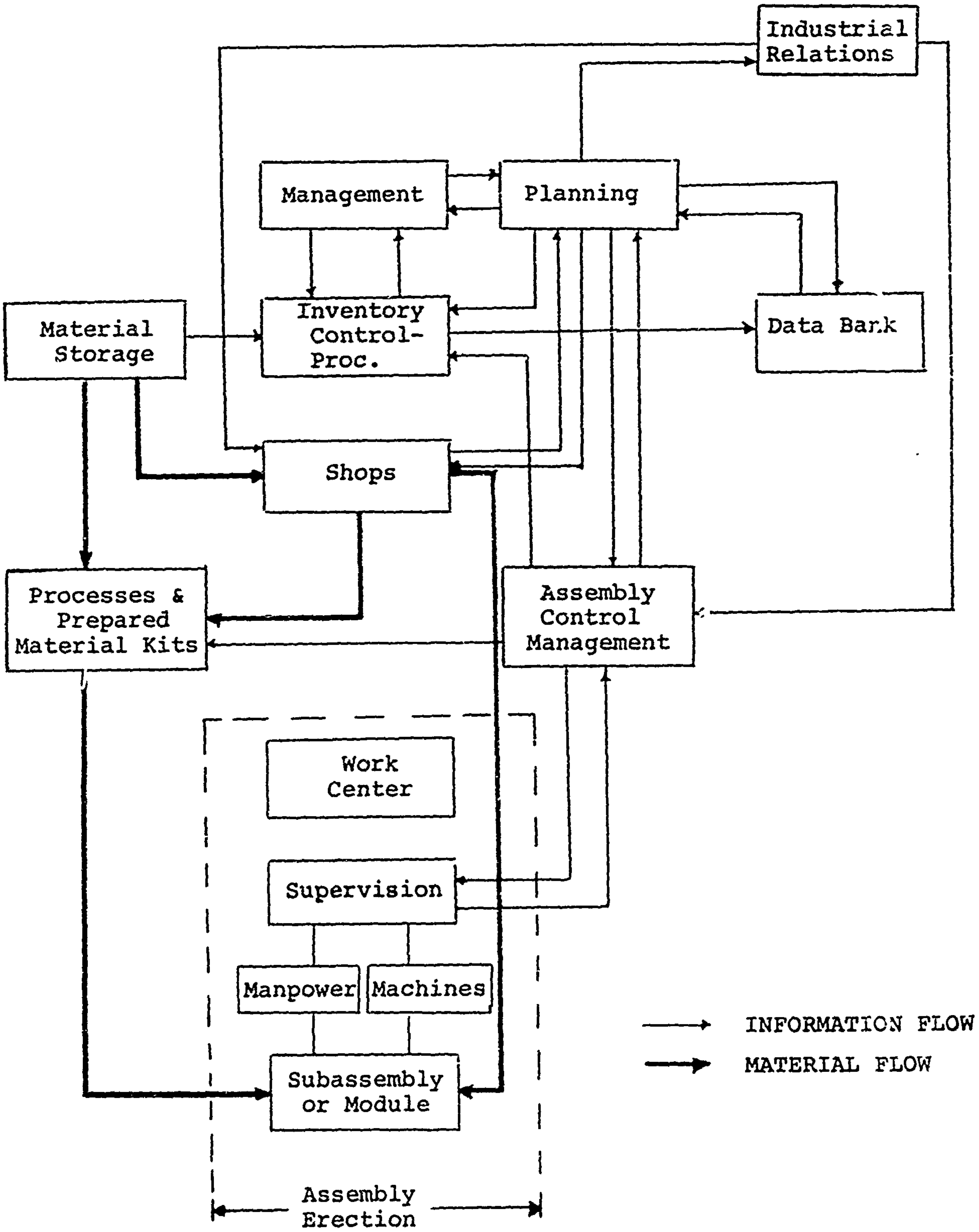
20) Cost center budgets and cash flow

21) Engineering and design reports

The information flow through the yards follows the intermittant production flow and, therefore, because of the discontinuities in a continuous production flow, a homogeneous information system is not necessarily ideal. The information system must be designed to meet the needs of each succeeding

Fig. 2.2

SIMPLIFIED YARD MANAGEMENT SCHEME



link in the flow. For example, the two most capital intensive facilities in a shipyard, the steel fabrication ship and the launching facility, require the lowest average labor intensity for the performance of their prime functions, see Table 2.1. On the other hand, assembly, outfitting and installation are activities which are normally capital extensive and labor intensive. This often creates the vast imbalance in labor and resource utilization throughout the yard, and the information flow must be based on levelling these activities.

In a modern ship production facility work functions are described by the work breakdown structure which defines specific and related work packages in a hierarchical manner. While the automated shops such as the steel fabrication shop have shop management similar to that of any continuous production or manufacturing process, other shops, and in particular the assembly areas, are organized by work centers as shown in Figure 2.2 which also indicates the required material and information flow in a simplified manner. The management control system is based essentially on effective integrated material and work or production flow by the provision of in depth control visibility on one hand andprecise directive information transmittal and control on the other hand. Work control is accomplished by detailed preplanned and scheduled material lists, drawings, isometrics, assembly sequences, measurement requirements, specifications, and work procedures, at the various levels of responsibility of the work centers. This implies that every skilled lead worker is supplied with exact directives as to how, where, and when his job is to be performed, and how it relates to the various interfacing work function.

The material lists supplied to the various levels of responsibility at each work center are time scheduled and referenced to the consolidated material kits which supply the work center with all the parts, subassemblies, materials, and special tools required for the performance of their work for a specific time inteval or job function.

The kits themselves are coded as a coordinated assembly of material supplies and fabricated materials and are planned to assure integration of related work or procedures. The material management is therefore delegated to assembly control management as indicated, which directs material kit development, buffer storage control, and material planning. As theprocessed and prepared buffer storage kits assemble all material supply and shop fabricated or preassembled material or subsystems, the assembly control management becomes the most effective production planning and control tool. Material storage, on the other hand, becomes a reporting and inventory function. The flow of the scheduled prepared kits is a work progress indicator as they specify work packages and can only be called for when a preceding planned and defined work unit in the work breakdown structure has been achieved.

The development of a ship production management and control system is basically concerned with the effective use and flow of information from the design through the production, erection and inspection phases of the shipbuilding process. In other words, we must efficiently transmit control information to machines and labor. The functional and operation sequence required for effective production must, therefore, be well defined, and an attempt be made to achieve functional integration and operational separation of the multitude of processes.

Information flow, storage, analysis and use is a subject which requires more thought than is usually devoted to it. Surplus and redundant data lead to uninformed and ineffective management and control. We must therefore introduce selectivity of information collection, transmittal and use at each level of decision making and control. In particular, the uncertainty or confidence in the data must be indicated to the decision-maker to assure the proper use of the information and the potential for the introduction of adoption or learning to the control process. Similarly, theadvantages of centralized versus decentralized data collection and storage as well as the resulting control will vary with each facility configuration and use. Ship production management and control functions can be summarized by the responsibilities of the four major decision blocks:

1) Engineering

   Drawing, Material Lists, Process Specifications

2) Process and Facilities

   Industrial, Production, andFacility Engineering Standards.

   Operation Sheets, Tooling, Jigs, Setups, etc.

3) Material and Production Control

   Production, Material, Procurement, and Warehousing.

   Master Erection, and Material Listing.

   Work Orders, Realization against Standards Costs.

4) Production Management

   Master Erection Schedule, Work Orders, Material Schedules, Inventory andDispatch Orders, Procurement.

A large amount of overlap is obvious from the above simplified listing. This is required though to assure proper control integration and information transfer.

2.2 Shipyard Control and Automation

Automation and control of ship production processes have become a subject of controversy in recent years. For our discussion, we will define automation as a means of translating information into action with a minimum participation of manpower. As in any industry, an application of automation requires a clear understanding of the complete information content of the operation to be performed. Information, therefore, defines the process to be executed.

In ship production we have both fixed and variable components of information, such as drawings, design data, material lists (bills of material), time sequences, erection schedules, procedural data, and environmental (location) data. The flow of information in a shipyard is further complicated by requirements for operator skills on improved or mechanized machines and processes. Similarly, the functional failure rate of machines, redundancy and fabrication tolerances capability must be introduced into the automatic analysis.

Techniques, machines and processes used in other industries for the accomplishment of similar functions have been studied to compare and improve shipyard fabrication and erection processes. In general, it is found that the introduction of automated or controlled processes results in quality improvement with a consequent reduction in rework requirements.

Automatic control to be successful must be integrated. There is little use in automating only one or some stages of a multistage sequential process. Similarly, automated processes usually require automated material handling. Automatic control may result in production cost savings, increased throughput, and such inferential benefits as quality, capability and intangible factors.

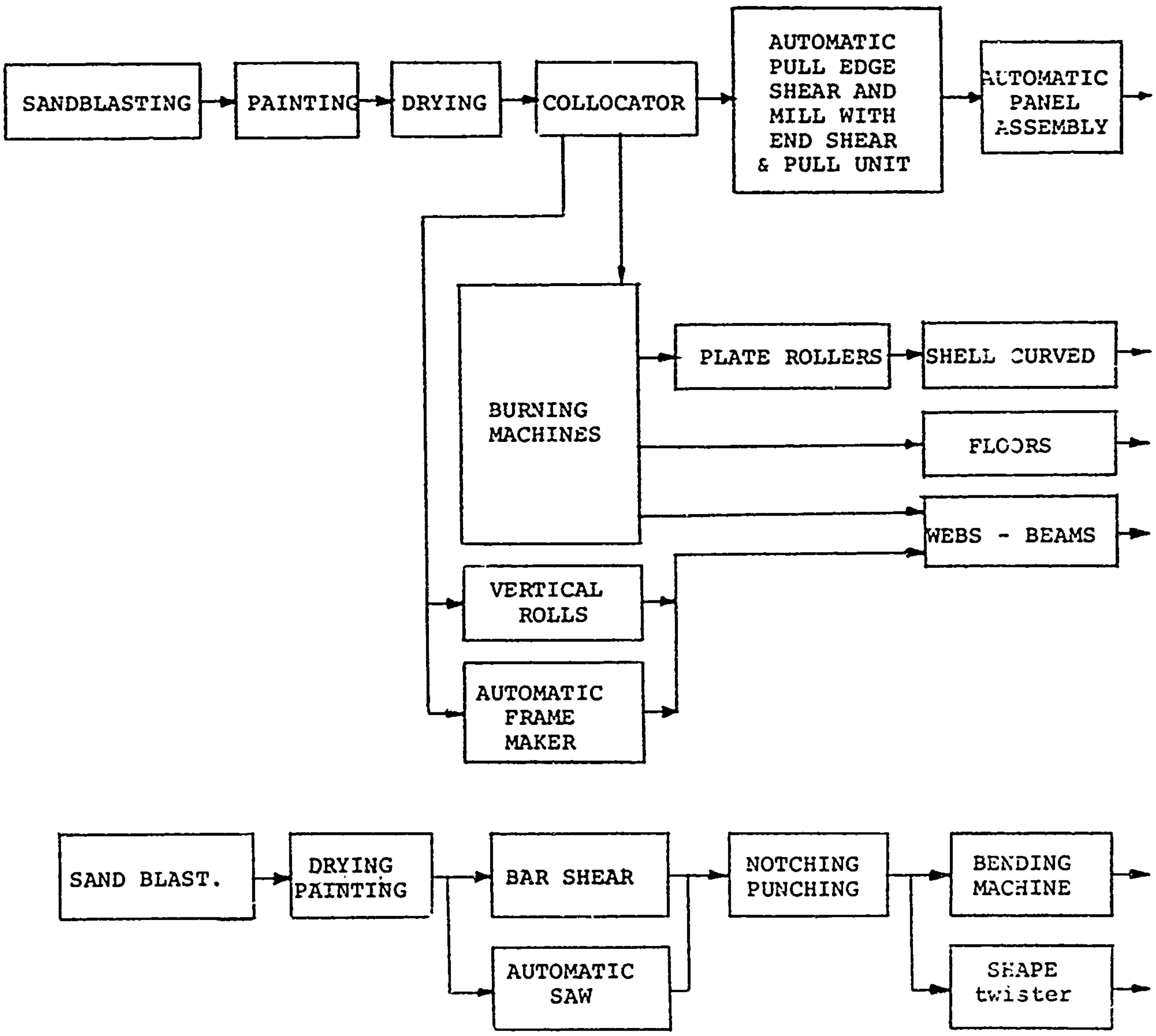
The availability of computers has induced a multitude of people to shift a large number of management and production control functions to computer control by numerical means. Although this approach is effectively used in many process industries with a well defined and consistent throughput and production requirement, the adoption of extensive numerical control for production, material, and information flow requirements in a shipyard are not as clear cut. It is found that a large number of modern shipyards who plan to use numerical control in a multitude of production processes under-utilize their control equipment or do not utilize numerical control at all. While many numerical methods for various stages of fabrication control and assembly control, including welding and material handling, are on the horizon, the effective use and the near term future (10 years) is doubtful in many cases. As computer technology progress works on a very short time frame and new generations of computer control equipment becomes available every two years, it may be unwise to adopt locked-in computer control systems for many of the production, fabrication, and material handling requirements at this state when their utilization is doubtful. It seems more important to assure a capability of future adoption of such control by the inclusion of extensive remote control capability for some of the major functions and the inclusion ofnumerical input capability. While much more available hardware can be effectively used today for MIS, a more detailed study of the most effective system should be made with particular reference to the relative advantages of centralization versus decentralization and the proper filtering of information at the various levels of management and control. Although computer hardware can be rented at nominal charges, it should be pointed out that these charges are normally only cheap if the computer iseffectively utilized. It is generally found, that once an extensive computer system is adopted, a vast proportion of the available computer capacity and time is utilized by make-shift or peripheral activities that are put on the computer simply because of redundant computer capacity and time. The vast majority of these activities would not normally justify computer usage were a computer not available anyway. Post factum analysis of theeffective cost of computer usage, eliminating activities not necessarily benefiting or efficiently handled by computer applications, often results in startling cost figures for computer use. In addition, it must be kept in mind that computer software has become a major, if not overriding, cost factor and a tremendous amount of thought must be given to the real needs in computer software requirements <u>before contracts are let for such development.</u> It must in particular be pointed out, that the software development (consultant or in-house) must be given very specific directions and requirements and must be able to warrant the effectiveness of the resulting software. We often find that unless this is done the developed software falls greatly short of accomplishing the desired functions. As a result, the utilization of the computers for MIS very often is marginal and imposes unexpected manual or human analytical functions which could or should have been introduced and effected by the software.

2.3 Steel Fabrication

The fabrication shop, shell assembly, and panel shop require detailed operation analysis including an evaluation of the statistical distribution of the thruputs through the various production lines, the line transfer requirements, resulting queueing problems waiting line and a waiting time analysis. The design of proper bufferstorage marshalling and handling facilities must be evaluated and various alternate configurations tested. Although the type, size and number of ships of any particular design to be built in a facility may be unknown, typical ships and ship runs can be developed and considered. By simulating the thruput, process, and fabrication requirements in these sequential processes, facility effectiveness for various alternative process line designs can be tested to assure the capability of maintaining the utilization and thruput of the various major components in this highly capital intensive facility. Experience in some shipyards abroad has indicated that small deficiencies in conveyor, material handling, transfer, or marshalling area capabilities such as speed differentials and stationary or mobile buffer storage may result in major degradations of thruput and utilization of the main production facilities and processes. The vast descrepancy between the proper piece/time requirements of various sequential plates, shapes, and the multitude of assemblies can easily lead to major bottlenecks, which seriously interfere with the production flow line. The conflicting interests of optimum sequencing of thruputs within the fabrication shop to utilize existing production line capabilities, on one hand, and the sequence requirements for feeding a large assembly area without major intermittent storage of fabricated components or parts very often leads to ineffectiveness within both the fabrication shop and its associated facilities and the assembly area unless detailed analysis and pre-planning is accomplished before locking into a fixed layout and production facility. Figure 2.3 presents a simplified block diagram of the steel fabrication process.

A shipyard plan or design based solely on steady-state thruput and fabrication requirements may lead to erroneous results. It can be easily shown that the statistical timerequirements in the various sequential steel fabrication processes varies by a factor of as large as three. The speed of transfer or conveyor systems is usually only designed to assure sufficient speed of delivery for the maximum thruput of the fabrication processes at the output point of the transfer or conveyor device. The large differences in thruput time requirements in the sequential processes can easily be shown to impose major increases in the conveyor and transfer speed requirements and the introduction of marshalling or weighting line spaces. These requirements cannot be established by consideration of steady-state thruputs or even by a consideration of maximum thruput capability or requirement. For a particular component of a piece of material sequential process times vary greatly.

Detailed simulation models using statistical thruput inputs will assist the development of the basic requirements for the design of such a facility and the required Management Information, Information Control, Production Control, and Process Control System. Such analytical models will also provide the means for testing various design or layout changes and their effect on capital costs, thruput, manpower loading, and material flow control. The design and layout, as well as control of the steel fabrication facility has a major effect on steel storage handling and control as well as the material control to the assembly areas. Network planning techniques, Monte Carlo Simulation and simple queuing models for isolated situation are some of the tools required for such an analysis.



Steel Fabrication
(Simplified)

Fig. 2.3

2.4 Production Planning and Management

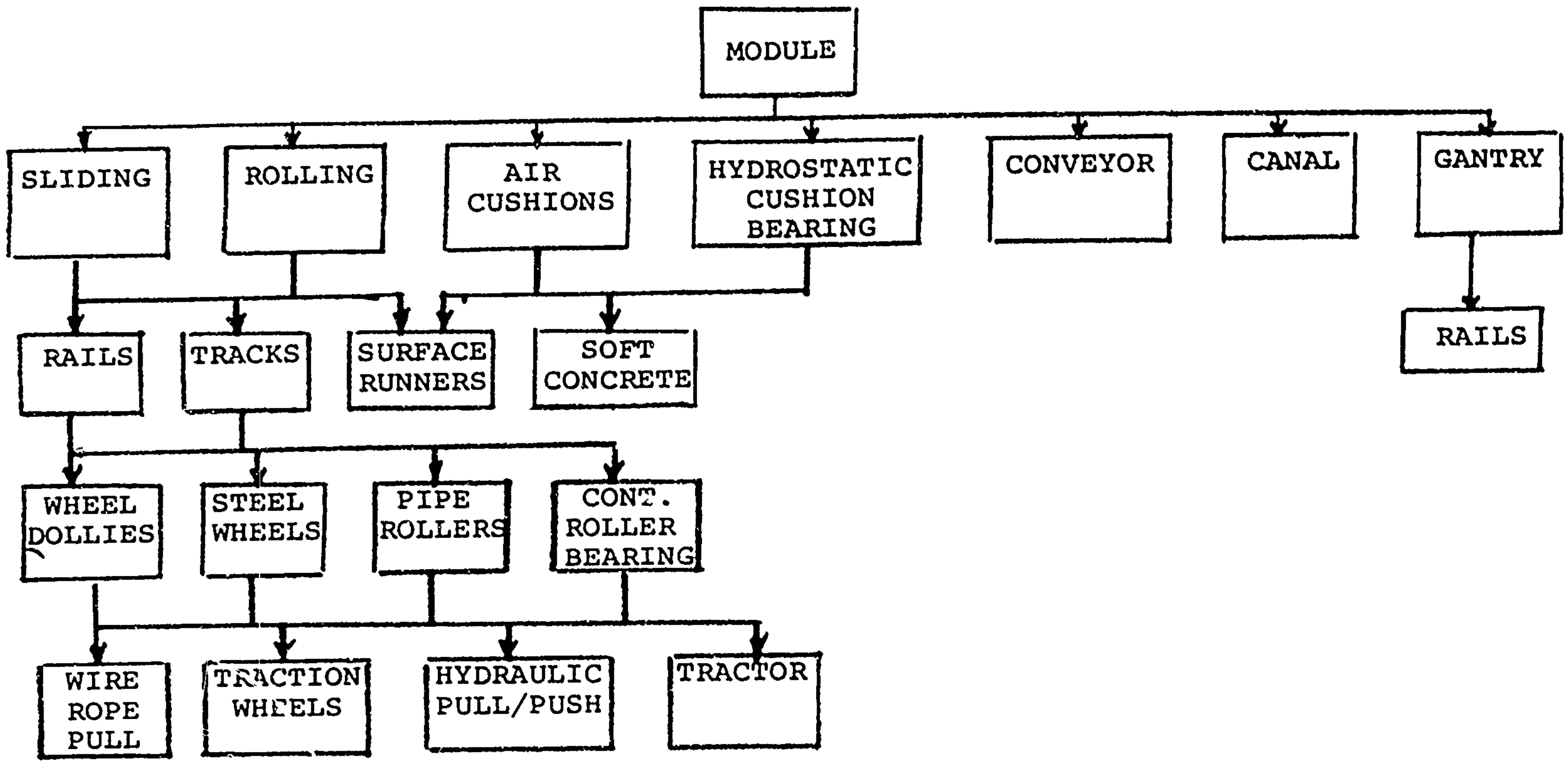
The production planning and the development of production control management systems require extensive analytical efforts using operations research techniques, critical path scheduling, PERT, and the multitude of planning analysis tools available today. The integration of production, material, and information flow into the control and management systems is imperative if a well coordinated management system is to evolve. The type of management and control system established must be custom designed to the facility layout and equipment designs. It has been found in the past that small changes in layout or design could result in greatly improved shipyard management and control if the management andcontrol systems had been designed concurrently with the yard itself, and if all the important interfaces had been traded off by a detailed analysis of first and operating cost. It is important to consider that a shipyard is a dynamic facility with large fluctuations in the thruput, management, control requirements, and large variations in workload intensity and manpower loadings throughout the yard. Management and control systems designed post factum to somehow manage a fixed shipyard layout and design will generally be less efficient than a control system which affected the layout and design of the yard by an evolutionary analysis.

The effective development of a system for control and transfer of information and material to the various work centers in the yard requires consideration of all important interfaces, including such factors as the statistical and dynamical marshalling and storage requirements at the various shop inputs or assembly areas. The control and management functions must be developed on the basis of the required operational sequences throughout the yard, which should be simulated by a model before the basic control and management structure is formulated. Such a procedure normally results in increased insight into the layout and design requirements of the yard and often results in drastic changes of concept and design as well as procedure.

2.5 Material Storage and Handling

Material storage in a shipyard must not be considered static. It is a dynamic flow function in which storage or warehousing provides buffer, accumulation, sorting andchecking space. The aim of a high productivity yard is to reduce the material in storage, handling, and process to a bare minimum consistent with sound, reliable oeprating procedures. Although intermittent supplies, transportation costs, strike or other risks, mass procurement cost advantages, etc., may cause larger-than-required stocks to be maintained, such policies have been shown not to pay in the long run. Storekeeping, the cost of capital in storage, degradation of stores, and other effectsmore than offset potential savings.

Material storage to be effective must be as close as possible to the place of immediate use and buffer storage a planned expedient. Line balancing and production planning can minimize buffer storage requirements. Storage should effectively serve manufactured and assembled components as well and be used to accumulate kits of material for specific work centers. The design of material storage facilities and areas requires a lot of thought and their effective use extensive planning, something which is seldom done. Material flow to and from storage, buffer and marshalling areas, must be unidirectional and result in a noncrossing, noninterference flow pattern. Simple material flow lines for the various defined material categories are readily design and time lines incorporated. The rate and intermittency of flow can usually be easily derived. It is surprising how often rather simple intuitive changes



Transfer Methods

Fig. 2.4

incorporated as a result of the obvious tangle first shown on a flow disgram can lead to major cost savings and productivity improvements. Material handling is a direct function of storage. It can usually be divided into:

1) Handling and initial storage upon receipt.

2) Handling and storage through fabrication, subassembly and outfitting shops.

3) Marshalling, buffer storage and distribution to outfitting, assembly and erection bays.

Material handling must be defined as planned movement and form an integral part of production flow. Handling methods must be entirely complementary to each other and transitions from one handling method to another must be facilitated by design.

The material handling and storage system, though labor extensive, has a critical impact on yard productivity. Unavailability or insufficiency of handling, transfer, movement or simple lift equipment may cause major holdups andresulting idleness of men, machine and production. The design of the track constrained and free moving equipment must form an integral part ofoverall yard design and planning and cannot be permitted to become an afterthought. Figure 2.4 indicates various module transfer methods. Material handling and storage design alternatives though functionally supporting production facilities, have to be included in the overall shipyard layout and separate shop or facility tradeoff studies. It is imperative to develop detailed cost and time networks with their statistical distributions and shortest/longest time constraint introduced by time-line analysis of separate movements. Linear programs for the tradeoff of crane size, capacity, reach, length of crane ways, hook height, crane way separation, etc., to assure adequate coverage of assembly, erection or shop areas, have been found useful. Particular consideration must be given to the use of non-tracked lifters or vehicles such as lowboy trailers, mobile cranes, Mafi trucks, etc., to assure that inefficient fixed rail cranes are used exclusively for lift, support and alignment or stationary crane transfer. A fixed rail crane to be effectively utilized, should lift its rated capacity during an average shift. Flow line handling balancing must be attempted in material handling system design and unit loads be made as large as possible. Store, outfit, or steel component items should be grouped into kit form on large steel pallets for effective material movement control and effectiveness.

Planning, scheduling, and control are overriding requirements in material handling and storage and cannot be overemphasized. These efforts must comprise the dynamic flow of materials throughout the yard and have effective feedback or management control capability. Furthermore, central material handling control must include feed of material to man and machines and should not stop at various hypothetical received and delivery points.

	Position	Amps & Dep Rate	Weld Speed	Wire Size & Flux or Gas	Distortion	Operator Skill	Joint Condition	Penetration	Physical Properties	Weld Preparation	Scaffold
Manual Shielded Arc	F H V&O	420-6 340-4.5 180-2.3	1" Pl--8"/Min 12 passes and Gouge	3/32"ø-- 5/16"ø	High	Low/Iron Pow. High for LoHi High for Cellulose	Dirty 1/8 - 1/4 Gap Bevel	Med.	Good	Expensive	No
MIG Shortarc	F H V&O	180-4	1/4"Pl--12"/ Min.	.032 ø	Pract. None	Moderate	Clean Any Gap Bevel	Low	Good	Fair	
MIG Sprayarc	F H	450-8 300-6	1" Pl--15"/Mi 6 Passes and Gouge	1/16 ø - 3/32 ø	Med.	High	Clean 1/16 Gap	High	Good	Fair	
CO_2 Flux Core	F H	650-15 450-10	1" Pl--18"/Mi 6 Passes & Gouge	3/32 ø - 1/18 ø	Low	Moderate	Inorganic Dirt - 1/16 Gap	High	Ex.	Expensive	No
Inner-shield	F H	600-14 450-9	Same as above	(above)	Low	Moderate	Same	High	Poor	Expensive	
One-Side Subarc	F H	1500X2 - 30 lb/hr	1" Pl - 12"/ Min	3/16 ø - 5/16 ø	Low	Moderate	Clean 1/8-1/4 Gap	High	Good	Expensive	No
Single Subarc	F H	1500 - 14 lb/hr	1"-20"/Min	1/16 ø - 1/4 ø	Med.	Moderate	Clean 1/32 Gap	High	Good	Expensive	No
Tandem Subarc	F	1500X2 - 30 lb/hr	1"-34"/Min	3/32 ø - 5/16 ø	Low	Moderate	DO	High	Ex.	Expensive	No
Electroslag Electrogas	V	700 -	1"-2"/Min	1/16 ø - 5/32 ø	Low	Moderate	Clean 3/4"-1" Gap	High	Good	Minimal	Vertical

Table 2.3

Welding Methods

2.6 Welding in Ship Production

Planning and effective use of available welding techniques is a prime shipyard productivity factor. Although familiar with modern welding methods, many U.S. shipyards do not make economic tradeoff study of the various welding possibilities as part of their production engineering and planning. Instead the decisions on methods, sequence and production details are often left to the working level. The large number of welding methods available today are complex and their particular advantages, capabilities and costs require expert welding production planning. Major cost/effectiveness/schedule tradeoff exists among the various automatic, semi automatic, special purpose, and hand welding methods such as: gravity welding, union melt, open arc, electroslag, counsumable nozzle electroslag, electrogas, etc. The percentage of application of automatic welding techniques in advanced shipyards is 15-22% of all welding material weight, while 50-60 can often be deposited by special purpose or semi automatic processes. Table 2.3 indicates the effective uses of various modern welding methods.

Welding production planning can be accomplished by an analysis of all major welds in the light of several alternative subassembly, assembly, and erection methods for every ship type. The length of the resulting vertical, horizontal and overhead welding and the material and thickness, etc., are all enumerated and various applicable welding methods and their resultant rates introduced into a large welding production tradeoff matrix. The grand total welding cost and time, the effect on production flow, cost and schedule are then evaluated and introduced into the overall ship production plan to assure the best mixture of production, fabrication, welding and assembly methods. Such an effort requires only about one man-month per ship and can be shown to be well worth the expenditure. For details on modern welding techniques, please refer to Ref. 14.

2.7 Tolerance Control and Alignment

To assure effective production flow in a shipyard an analysis of tolerance capability and requirements of the various production and assembly stages in necessary. Similarly, tolerances must be translated into alignment requirements. On the basis of recent tolerance recommendations, the following accuracy requirements can be established.

1. Steel plate, lengths and widths tolerance 1/16"
2. Straightness at plate edge for automatic welding 1/64"
3. Straightness at plate edge for manual welding 1/32"

The tolerance requirements are based on the following approach:

(a) Accuracy in Machining. - Machining of the elements, which will later be used for prefabricating a unit, is to be done with such accuracy that the platers and welders in the assembly shop can use their time for primary production and not for correction of faults in the elements produced at previous stages.

(b) Accuracy in Prefabrication. - The units should be produced with such accuracy that joining up on the berth gives the minimum of correction and fitting work.

(c) Quality Requirements. - Not only correct dimensions but also good general quality of workmanship has to be maintained.

In addition to the above stated requirements in machining, the accuracy of edged planning should be within 1/64".

The tolerances guaranteed by steel mills are normally above those required for the manufacturing process of an automated shipyard. Dimensions of steel plate have a standard deviation of 1/4" for standard mill plate. This implies that over 5% of all plate may deviate by as much as 1/2" from their defined lengths or widths dimension. Similarly, shapes such as flat iron of breadths exceeding 2"normally varies about +2%. Angle bars with flat widths in excess of 3" deviate by ± 1/8". Other shapes deviate by roughly the same proportion of their defined dimensions. Large flange shapes with flanges in excess of 10" normally carry a guarantee of a ± 2% deviation in depth and width. These tolerance guarantees are normally inadequate from a structural strength as well as cost point of view. When sections of various depths are to let through a bulkhead, alignment, watertightness, as well as production costs, are a matter of concern. It appears advisable to investigate the feasibility of reducing the guaranteed tolerances and develop a tradeoff study to indicate required recommendations.

In the shop subassembly area where the largest degree of tolerance control can be maintained, finished units such as flat stiffened panels and other subassemblies are mainly affected by:

1. Tolerances in the machined elements.
2. Shrinkage or distortion effects of welding.
3. Assembly faults during prefabrication.

The size and shape of the subassembly is of major importance in estimating the distortion and production inaccuracies introduced in subassembly. In order to assure the maintenance of the required tolerances for the build-up of major subassembly sections in the module production line, the shop-fabricated subassemblies must be maintained within 1/8". This will permit maintenance of tolerances of less than 1/4" for three-dimensional shapes built outside the shops. It should be remembered that neither the quality nor the cost of burning or welding in the open assembly areas can compare with equivalent work performed in the shop. Poor burning leads to an increase in deposited weld metal and results in increased building costs.

The use of optical measurement techniques in the subassembly area for both two-dimensional as well as three-dimensional measurement and alighment seems to offer major advantages. Such measurement techniques have been developed by the Russians and are described in Sudostroenie, No. 1/61. It appears also appropriate to evaluate required tooling and jigs to assure maintenance of tolerances and alignment adjustment capability in the subassembly area. The cost of tooling will be traded off versus additional production and material handling cost. Detailed evaluations of the effects of tolerance buildup defined by major structural dimensions is essential. The basic control of the tolerances depend on the statistical methods applied which are simple and founded on a Gauss' Distribution. An evaluation of a large amount of material and production data by C. E. Frederiksson, presented in a paper in 1962 transactions of RINA, indicates that a Gaussian tolerance distribution assumption is valid. The following table, derived from the same paper, summarizes the machining and prefabrication requirements defined from this statistical study for the Swedish Shipyard of Eriksberg, Sweden.

MACHINING	TOLERANCE
(a) Plate-work (Nominal length > 10 m.)	
(1) Optically-guided burning machine on scale 1 : 10	$\pm$1/16"
Including: Production of templates. The shrinkage of template material. Burning machine.	
(2) Manual work	$\pm$3/32"
Including: Production of templates. Marking off. Manual burning. Excluding: Template material.	
(b) Sections Manual work	$\pm$3/8"
Prefabrication (Nominal dimension $\geq$ 10 m.	
(c) Sections Manual work	$\pm$3/8"
Prefabrication (Nominal dimension $\geq$ 10 m.	
(1) Two-dimensional units without correction after welding	$\pm$3/32"
(2) Two-dimensional units including correction after welding	$\pm$1/16"
(3) Three-dimensional units	$\pm$1/4"

The above figures are consistent with the conclusions reached by the analysis made in Russia and reported in the transactions of the Leningrad Shipbuilding Institute. The stated values are rigid three-dimensional sections such as double bottoms resulted in standard deviations of less than 1/10", with publication tolerances in overall lengths or breadths dimensions of the order of 5/16".

The major consideration in the alignment of double bottom in the erection process is the hysteresis and creep deformation of the keel blocks and other supports when made of timber. Lowering of the ship's bottom by as much as 1" may be caused by these effects. Other considerations in the measurement of three-dimensional assemblies during the module erection process must consider welding shrinkage forces, temperature variations and various support deformations caused by unsymmetrical loading during the erection. As a result, we will have to consider measurement corrections as required to make up for unsymmetrical loading deformation during the erection process. A detailed analysis of the interaction of welding shrinkage, loading, and differential temperature induced forces and their effects on subassembly and module dimensions must be analyzed to permit proper evaluation of the actual dimensions taken during the production process.

2.8 Measurement Techniques

Various measurement techniques are applicable to the ship production process. Their proper choice has a major effect on the productivity of the yard and the quality of the product.

(1) Physical/mechanical one-directional measurements. This type of measurement includes one-directional dimension measurement such as the use of steel tape measures, as well as measurement of angles by mechanical means.

(2) Optical measurement techniques. Optical measurement techniques are one- and two-dimensional and consist of Theuodolide type operators or optical project techniques, which essentially simulate the use of mechanical templates. One-dimensional optical techniques can also be used for two- and three-dimensional measurements by the incorporation of angular scales.

(3) Laser and other high intensity light measurement techniques. The use of these techniques, which consist of columnated light applications, introduce additional accuracy and flexibility into theoptical measurement approach. Various operators are available and high sensitivity scales can easily be graduated to any degree of accuracy required. This method permits the measurement of large three-dimensional shapes to a high degree of accuracy.

Both types of optical measurement techniques rely on fixed and defined reference points. A popular laser technique in extensive use in the aircraft industry employs helium-neon gas lasers to achieve 5-1` times higher accuracies than standard alignment telescopes and are about 3-5 times faster to operate. Some of these laser techniques are today available with couplings to alignment jigs, presses and other tools to exert positive control. Interferometer readouts show the wavelengths of light the reflecting mirror on the aligned workpiece has moved which is compared with the intended distance including a precalculated allowance for springiness. Laser applications reduce dependence on observer and target positioner. Active targets sensed photoelectrically by linear displacement monitors eliminate communication, add accuracy and speed, and introduce direct control capability.

In addition to the applicability of laser techniques to steel assembly and ship erection processes, they provide a unique new and effective measurement and control device for contour analysis, to control and measure shell bending and curved assembly fit and alignment. Hydraulic positioners and bending rams can be controlled directly by a tooling laser. Measurement accuracies of 0.005" over 200 ft. and machine control accuracies of 0.001" are usually achieable. Although largertolerances are permissible in ship production work, the low cost of laser tooling ($4,000 including accessories) certainly warrants consideration of these methods.

Conventional and novel measurement methods are presented in Figure 2.5. While the use of standard jig gages, scales, optical tooling, steel tapes, transits, levels, etc., is applicable to subassembly production, real time measurement-alignment techniques are required for effective module or ship erection if high assembly efficiency is to be achieved. This can be accomplished by use of light-sensitive or scaled targets mounted on corner points to provide the out-of-alignment measurement signals which serve as inputs to the mechanized alignment tooling. The importance of 6 degrees of freedom measurement and alignment capability is very important. Such methods have been effectively developed and used to assemble large missiles and building and can be designed for integrated real time computer control.

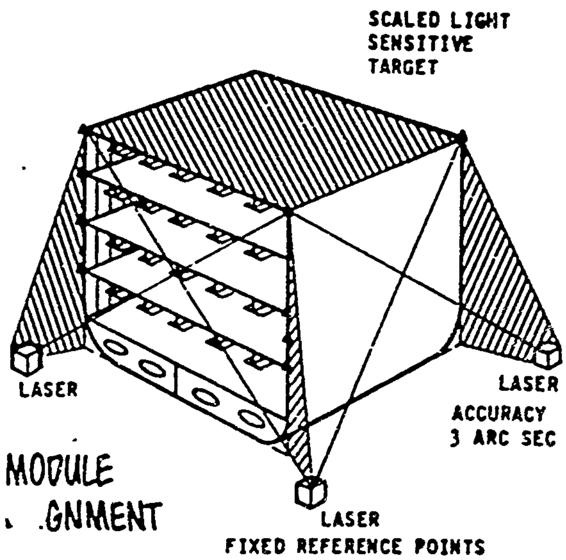
Dimensional controls must be established by production engineering prior to production start-up and maintained throughout the fabrication and erection process. The same applies to dimensional control of non-structural elements, to assure proper marry-up.

The various methods proposed for measurement and alignment control must be advanced and reliable yet practical and accurate over the entire range of size and weight to be handled.

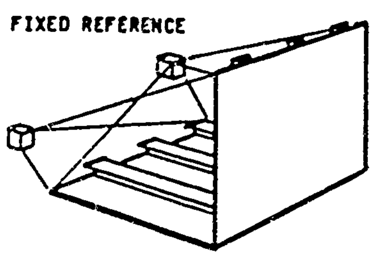
Interference Control

Internal alignment and interference control of non-structural members and particularly distributed systems is a major production engineering function. Although effective programs for the layout, engineering, adjacency, clearance, and interference requirements are becoming available, simple and effective methods for space allocation on a priority basis can be used. These methods rely first on the allocation to large, expensive, inflexible systems such as heavy pipe, ducting, etc. which are followed by a ranking of more flexible or inexpensively installed systems. Support, insulation, clearance, access, etc., can be incorporated and the interference program can be used to track variations from designed configurations to correct subsequent systems.

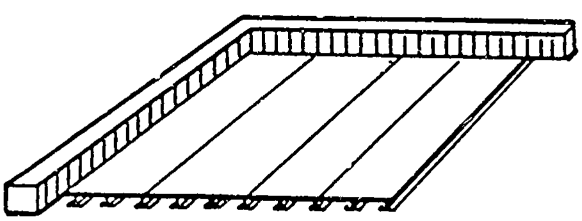
MEASUREMENT AND ALIGNMENT



MODULE ALIGNMENT



3 DIMENSIONAL SUBASSEMBLY ALIGNMENT



FLAT PLATE ALIGNMENT

MEASUREMENT MEANS

		LENGTH	CURVATURE	GIRTH	ANGLE
1. Sub Module Components					
	a. Tape	X	X	X	
	b. Scales	X			
	c. Straight Edges		X		X
	d. Templates, Jigs, Fixtures	X	X	X	X
	e. Numerically Controlled Machines	X	X	X	X
	f. Transit, Dumpy Level, etc.	X			X
	g. Calipers	X			
	h. Gages	X	X		X
	i. Protractors				X
	j. Visual	X	X	X	X
	k. Photocell/Light		X		
	l. Planimeters	X		X	
2. Sub Modules					
	a. Protractors				X
	b. Tapes	X	X	X	
	c. Scales	X			
	d. Straight Edges		X		X
	e. Templates	X	X	X	X
	f. Jigs	X	X	X	X
	g. Fixtures	X	X	X	X
	h. Gages	X	X		X
	i. Calipers	X			
	j. Transit, Level, Theodolite	X			X
	k. Ultrasonic	X			
	l. Interferometric Equipment	X			
	m. Lasers	X			X
	n. TV	X			
	o. Visual	X	X	X	X
	p. Photocell/Light	X			
	q. Autocollimators (Automatic & Manual)	X			X
	r. Light Beam/Prism (Time Delay)	X			X
	s. Radar	X			X
3. Partially Completed Modules					
	a. Protractors				X
	b. Tapes	X	X	X	
	c. Scales	X			
	d. Templates	X	X	X	X
	e. Gages	X			X
	f. Transit	X			X
	g. Level	X			X
	h. Theodolite	X			X
	i. Laser	X			X
	j. TV	X			
	k. Visual	X	X	X	X
	l. Autocollimators	X			X
	m. Light Beam/Prism	X			X
4. Modules 5. & Double Modules	a. Tape	X	X	X	
	b. Scales	X			
	c. Templates	X	X	X	X
	d. Transit	X			X
	e. Level	X			X
	f. Theodolite	X			X
	g. TV	X			
	h. Autocollimators	X			X
	i. Laser	X			X
6. Partially Completed Ship & 7. Ship	a. Tape	X	X	X	
	b. Scales	X			
	c. Transit	X			X
	d. Level	X			X
	e. Theodolite	X			X
	f. TV	X			
	g. Laser	X			X

Fig. 2.5

2.9 Assembly, Erection and Launch

A large number of combinations of subassembly, assembly, erection and launch methods are available for consideration in the design of a modern ship production facility as shown in Figures 2.6 - 2.7. Stationary ship erection where the ship is assembled by structural blocks lifted onto the launch platform (dock, way, etc.) requires a tremendous labor intensity in a small area and/or volume with resultant productivity degradation, reduced quality and high capital costs in relation to productivity. Methods whereby launch, erection and assembly are performed in separate and specialized locations permit the spread of labor over a large area, better utilization of capital equipment, and lower capital investment for the same production rate. This approach furthermore introduces flexibility in the size of ship and assembly as well as in the number of different types of ships built concurrently. It also permits close scheduling and effective action to correct production holdups by permitting bypass of assemblies.

The utilization of material handling equipment is greatly increased by such an approach and outfitting spread over a very large area which in turn permits a much higher completion of outfitting work as is usually accomplished by stationary erection methods.

Modern automated or semi-automatic welding can be effectively applied to a much larger extent and material flow can be effectively controlled and scheduled. The various assembly stages and areas are most conveniently defined by an analysis of assembly size stages. Blocks of 20-50 tons, 50-200 tons, and 200 tons and above are established for the various expected ship types, and the number of block assembly spaces calculated. This permits the development of assembly area design and material handling system requirements defition which, in turn, provide the inputs for the assembly and erection layout alternatives which are then manloaded. We next establish time lines for the structural and outfitting work accomplished at each station, to compute assembly residence times and material handling requirements. All of these form the inputs to the layout tradeoff studies by which we determine the final layout and equipment selection.

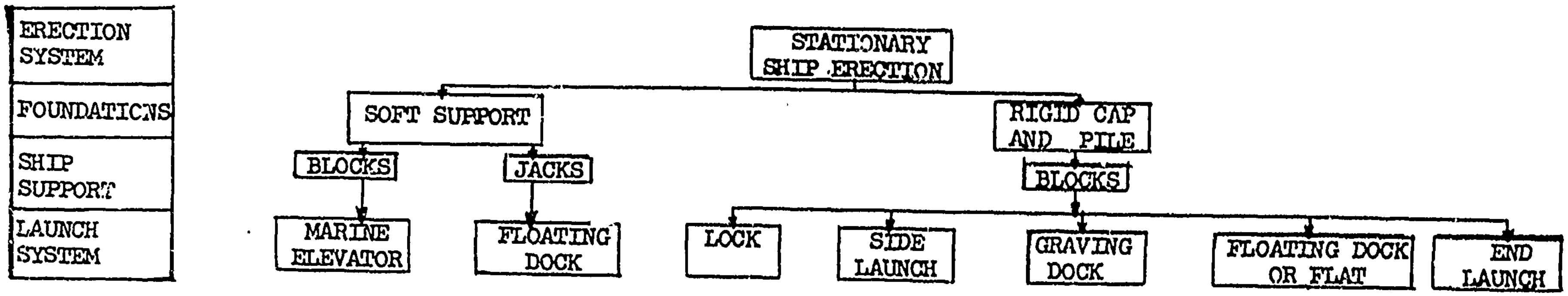


Fig. 2.6 Stationary Ship Erection

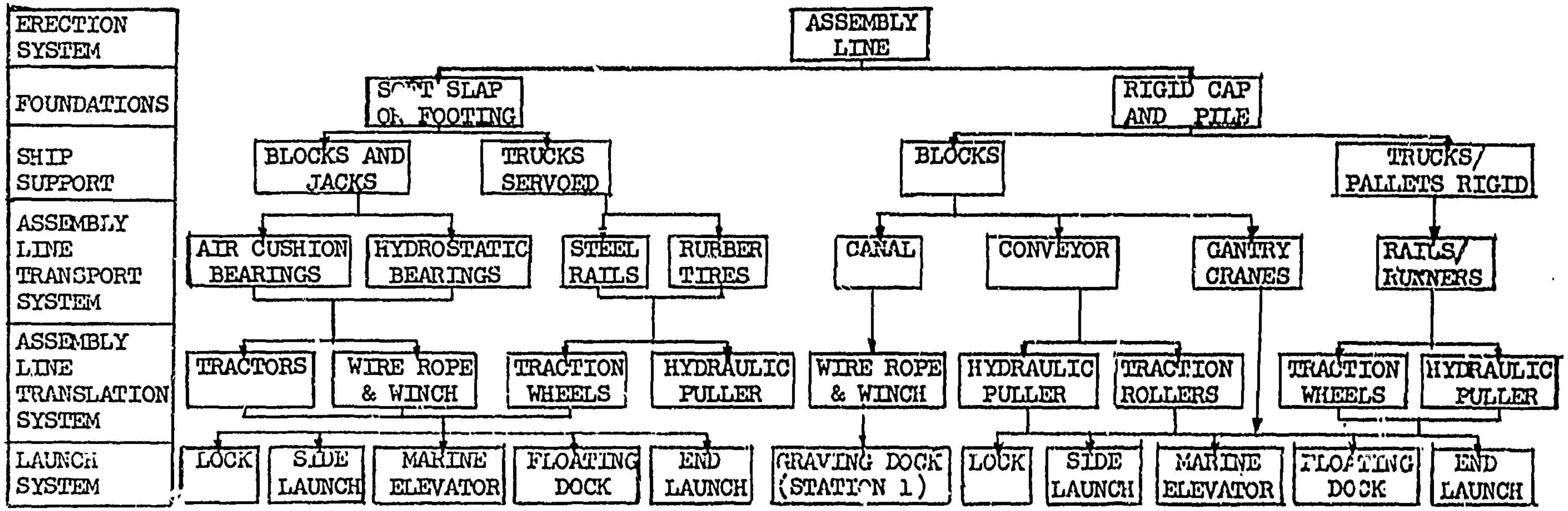


Fig. 2.7 Assembly Line Ship Erection

2.10 Outfitting

In a modern ship production facility the assembly of machinery and outfitting components is a sequential process where material is added at a work station to form a complete machinery or outfitted sub-module. Foundations, deck pallets, or partial bulkheads are equipped with:

1) Purchased machinery from the machinery storage areas.
2) Hull outfitting items, miscellaneous hardware and expendables from machinery or general storage.
3) Sheet metal ducting and accessories.
4) Fabricated electrical wire cable, fixtures and electrical equipment and components.
5) Fabricated piping and pipe assembly components including bilge piping.
6) Miscellaneous steel outfitting and small steel flats from the steel fabrication shops.

False stanchions or bracings are often required to permit effective handling of the assembly during erection, when assemblies are listed into or onto module or steel assembly or slid sideways into it. Machinery preassembly and outfitting does not only introduce greatly increased productivity by spreading high intensity, highly skilled work over a larger easily accessible and convenient area, but has also been found to result in higher quality work and increased pretest or calibration capability. It should be noted that up to 25% of all ship production manhours are spent in or for outfitting the machinery space, which is normally a veritable beehive. Every effort must therefore be made to spread and control this work if an effective increase in efficiency and quality is to be attained. Machinery modules are installed in sequence around the main machinery which can be installed on its foundation which is normally an integral part of the hull structure, in the shop if continuous or as separate subassemblies on the tank-top if intercoastal.

The main purpose in the selection of the erection/launch method, and overall assembly layout is the desire to decentralize labor intensive activities and spread them over as large an area of the yard as possible. This also affected the layout and location of individual shops surrounding the assembly area. Finally, the same philosophy is applied in developing the outfitting procedure and the post-launch outfitting efforts. An attempt should therefore be made to assure as much concurrent outfitting during production and assembly as practical. Finally, an effort is made to develop effective measurement and alignment techniques to reduce erection effort and the requirement for corrective action. A large number of potential measurement and alignment techniques with particular reference to some of the modern techniques developed for the erection of large missiles and similar structures have been analyzed. As a result, a combination of various optical alignment and measurement techniques, including autocollimators, lasers, light team - prisms (time delay), and others, should be considered, for the outfitting efforts.

Outfitting requires the largest amount of preplanning and rigid scheduling. It is here that the greatest benefit can be derived from an effective application of computer-aided design fabrication and control. Currently developed electrical and other distributed systems layout and interference programs can be applied to the manufacturing and preinstallation of outfitting components with major savings in cost and time.

2.11 Conclusions and Recommendations

An attempt was made to present some of the highlights, thoughts andfindings affecting modern ship production facility design. The confines of a paper do not permit a discussion in depth of any of the numerous aspects of this problem. The most important conclusion reached by the author, after involvment in shipyard design over many years, is the importance of effective production engineering, process and management planning. We cannot expect to be able to design and operate modern automated ship production facilities by intuition no matter how much it is backed by experience.

It is interesting to note that modern successful ship production facilities employ roughly 10 times as many qualified engineers and naval architects as the average equally large U.S. shipyard. This factor is amply justified by the vast increase in productivity achieved by detailed planning, scheduling and control.

It appears that in existing yards much larger improvements in productivity can be achieved by effective application of trained, forward-looking, experienced brainpower and a limited use of capital improvement, than by a massive seat-of-the-pants investment of capital.

3.) U. S. Shipbuilding Capability and Capacity

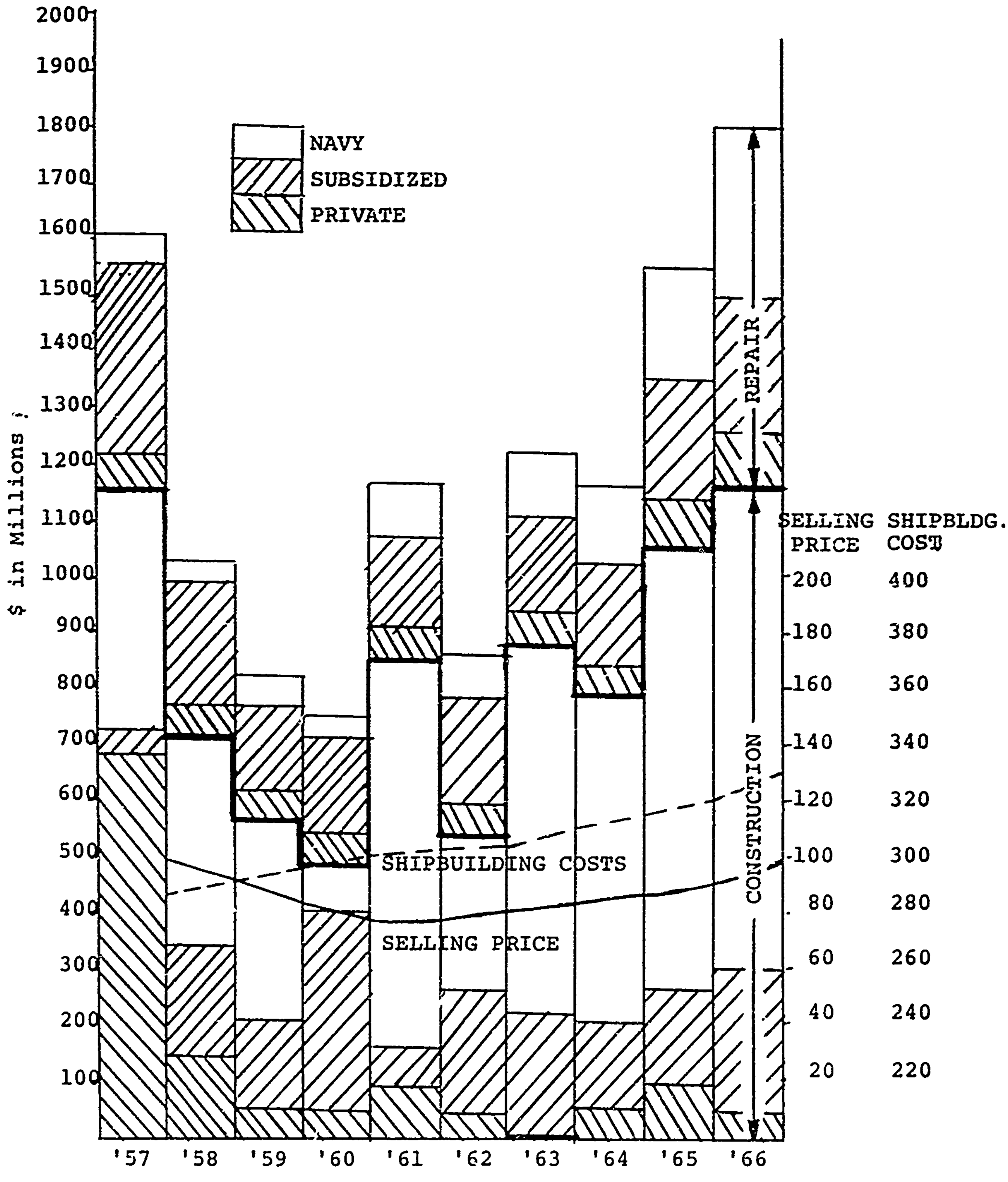
The shipbuilding industry of the United States consists of 21 major commercial yards building ships 475' and over, 6 commercial yards building ships of 300-475', and 9 naval shipyards. In addition to the ship repair work performed by building yards, another 52 commercial ship yards specialize in repair and conversion work. The employment level in the United States shipbuilding industry is presented in Table 3.1, while Fig. 3.1 indicates the dollar sales value of ship construction and repair work available to the commercial yards. As a result it can be seen that the total annual cash flow per employee is $15,200. Considering that about 47.2% of this cash flow or sales volume is accounted for by "buy" items in the awards, the annual sales per employee reduce to just under $8,000.

This sales award level is among the lowest of any capital industry in the United States. Over the last decade, over 65% of all the ships built in U.S. commercial yards were naval vessels, while an additional 19% were built for Government accounts or subject to Government subsidy. Therefore, less than 16%, and the percentage is dwindling, of the orders received by the industry are not directly affected by legislative decisions on a year by year basis. While the number of ships under construction by the industry varied by about 20-25% per year, the dollar volume varied by a somewhat larger percentage. Shipbuilding costs as indicated in Fig. 3.1 have risen by about 3.2% per year in the last decade, yet ship prices have actually fallen, until a bottom sale/cost level was reached in 1961. The selling price has since risen roughly 3.3% per year in line with increased shipyard utilization.

TABLE 3.1.

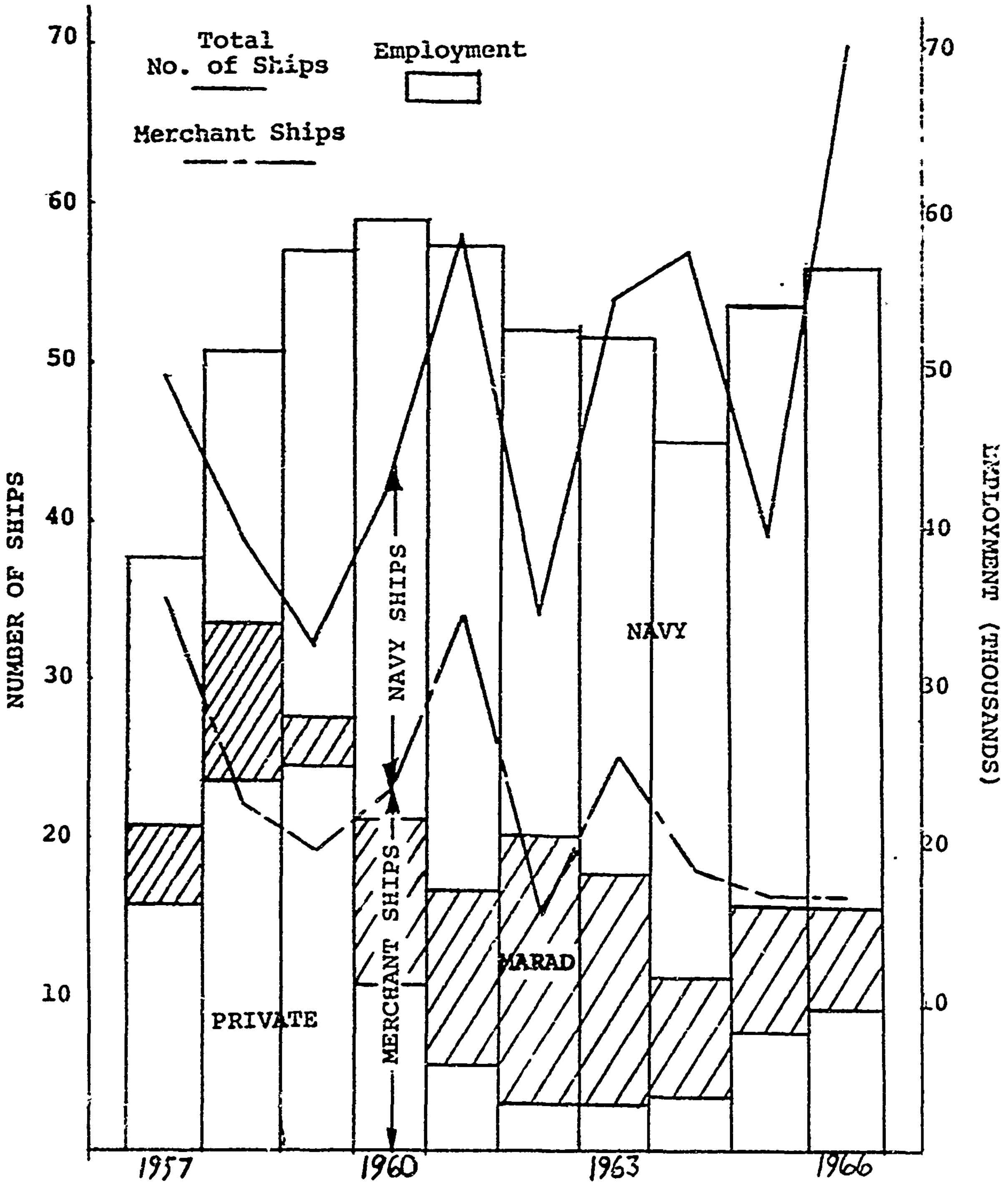
SHIPBUILDING AND REPAIR
TOTAL EMPLOYMENT
JUNE 1966

Category	No. Yards	Approximate Employment
Naval Shipyards	9	82,800
Commercial Repair Yards (No new construction)	52	23,800
Commercial Shipyards (475'and over)	21	53,750 (New Construction) 16,100 (Repair)
Commercial Shipyards (300'-475')	6	27,700
TOTAL	88	204,100



Private, Subsidized and Navy Work
Dollar Value of Awards (Construction & Repair)
and Index of Estimated Shipbuilding Cost and Selling Price

Fig. 3.1



Ships Ordered from Major Private U.S. Shipyards
and Resultant Employment
(Vessels of 1,000 gross tons and larger)

Fig. 3.2

TABLE 3.2

SHIPS UNDER CONTRACT AS OF 1 JUNE 1967

21 Major Shipyards	No. of Orders	$ in Millions
East Coast		
Bath Iron - Bath, Maine	5 Navy 3 Marad	103.1
General Dynamics - Quincy, Mass.	16 Navy	422.8
New York Ship - Camden, New Jersey	1 Navy	33.5
Sun - Chester, Pennsylvania	7 Marad 2 Pvt.	131.2
Bethleham Steel - Sp. Pt., Maryland	2 Navy 8 Pvt.	137.8
Maryland - Baltimore, Maryland	1 Navy Conv. 4 Pvt. Conv.	26.5
Newport News - Newport News, Virginia	12 Navy 5 Marad 5 Pvt. Conv.	554.1
West Coast		
Nassco - San Diego, California	20 Navy	308.2
Todd - San Pedro, California	8 Navy	93.8
Bethlehem Steel - San Francisco, Cal.	(None)	(None)
Lockheed - Seattle, Washington	18 Navy	281.2

(continued)

TABLE 3.2
(continued)

	No. of Orders	$ in Millions
Great Lakes		
American - Toledo, Ohio	1 Marad	8.4
American - Lorain, Ohio	8 Navy 2 Pvt.	26.7
Defoe - Bay City, Michigan	5 Navy	41.3
Christy - Sturgeon Bay, Wisconsin	1 Navy	5.5
Fraser - Superior, Wisconsin	(None)	(None)
Manitowoc. Wisconsin	(None)	(None)
Gulf Coast		
Alabama - Mobile, Alabama	(None)	(None)
Ingalls - Pascag, Mississippi	7 Navy 14 Marad	385.0
Avondale - New Orleans, Louisiana	34 Navy 8 Marad	479.2
Bethlehem Steel - Beaumont, Texas	(None)	(None)

The larger repair volume handled by shipyards in recent years is the main factor permitting fairly constant overall industry employment level. On the other hand, private shipbuilding has been able to handle an increasing new constructions volume with a constant level of work force which is indicative of increased productivity.

While overall employment in the industry only fluctuates by about 10-20% between years, much larger variations in work force are experienced by individual shipyards.

The 21 major commercial shipyards comprising the backbone of the industry and their 1967 backlog are listed in Table 3.2. These shipyards have a total production capacity of 61,400 tons of steel per month, or an annual rate of 0.73 million tons. They own 8 (7 excluding New York Shipbuilding) large 800' or longer graving docks, of which 5 are used for construction. Another 10 large graving docks are owned by the U.S. Navy, though only 7 of these are considered active, (Figure 3.3). The total shipbuilding capacity of the industry is difficult to estimate as a result of differences in ship types, productivity, intensity of facility utilization, and other factors. Figure 3.4 indicates the trend in ship parameters. As the bulk of commercial shipbuilding in this country was devoted to break bulk cargo ships, the industry was not required to satisfy the large changes in ship dimensions introduced by mammouth tanker and bulk carrier requirements. Yet even the high performance cargo lines, large carriers, and container ships currently on order stretch the large ship construction capability of the industry to the limit. We not only lack ways and docks to build the number of large ships required, but also

Fig. 3.3 U.S. Graving Docks in Excess of 800' Length *

(Total Number - 18)

Location	Length	Breadth	Over Sill	Over Keel Blocks
Commercial Yards:				
BOSTON, MASS.:				
Commonwealth Drydock Co.	1176'	133"	-	42'
General Dynamics Corp., Electric Boat Div.	875' **	132'	28'	24'
	875' **	132'	28'	24'
	941' **	150'	28'	24'
CAMDEN, N.J.: New York Shipbuilding Corp. (inactive)	1100'	150'	41'	43'
NEWPORT NEWS, VA.:				
Newport News Shipbuilding & Drydock Co.	862'	118'	30'	29'-4"
	960' **	123'	37'	35'
	1100' **	135'	42'	40'
U.S. Navy Yards				
San Francisco Naval Shipyard - Hunters A.	1092'	143'-2"	47'	43'
	999'-1"	114'-4"	40'	37'-7"
Bremerton Naval Shipyard, Wash.	867'	113'	38'	35'-6"
	927'-3"	123'	23'-6"	18'
Long Beach Naval Shipyard, L.A.	1092'	143'	43'	-

* There are no floating dry docks in existence which will receive ships of this length.

** Used as building ways.

(continued)

Fig. 3.3 (continued)

Location	Length	Breadth	Over Sill	Over Keel Blocks
New York Naval	1093'	150'	41'-1"	38'-1"
Shipyard	1093'	150'	41'-1"	38'-1"
(inactive)				
Bazome N.J. Annex	1092'	151'-4"	47'-4"	42'-10"
Philadelphia Naval Shipyard, Pa.	1022'	127'-6"	43'-5"	-
Norfolk Naval Shipyard, Va.	1005'	118'	43'-9"	40'-3"

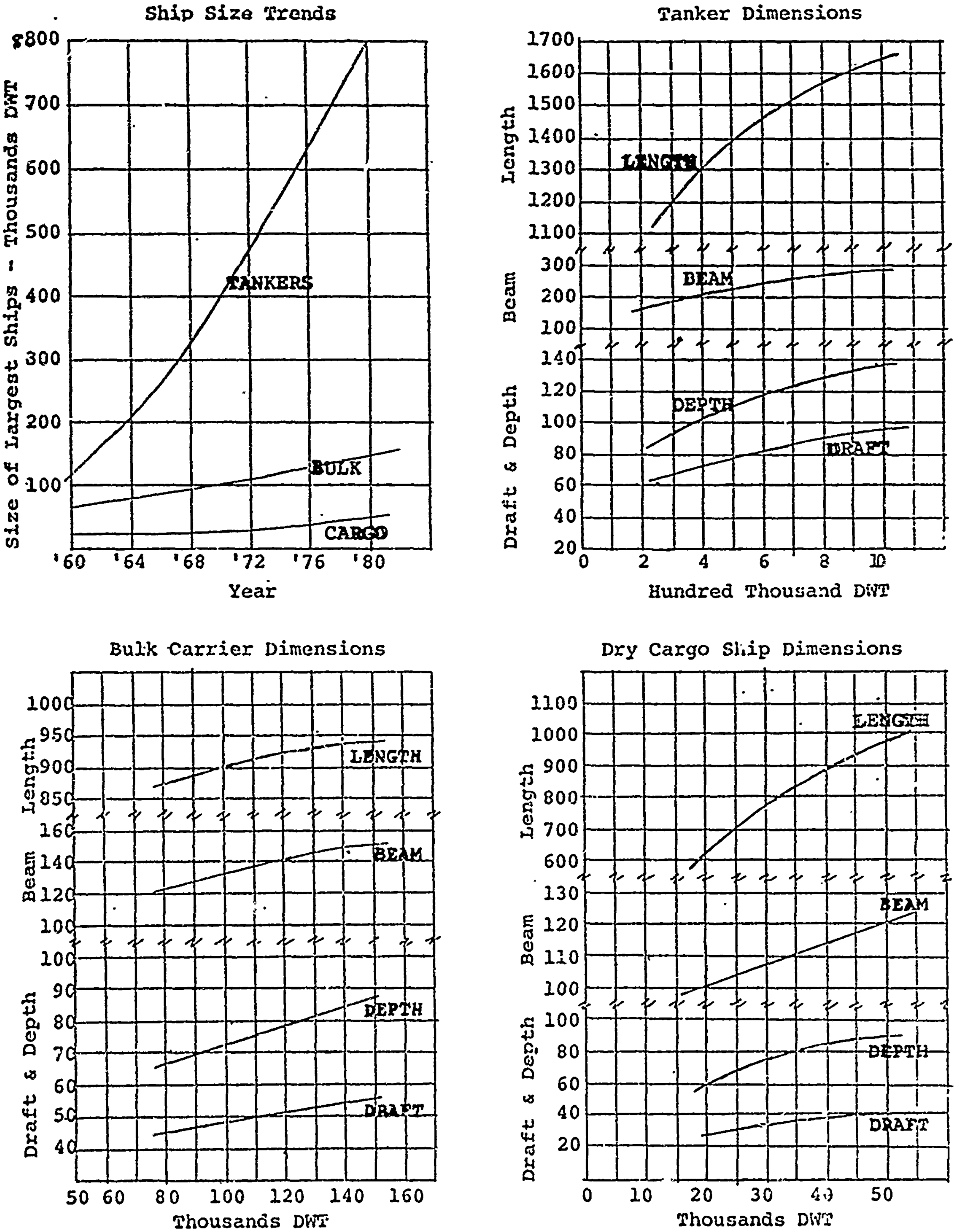

Ship Size Trends
Size of Largest Ships - Thousands DWT
800
700
600
500
400
300
200
100
TANKERS
BULK
CARGO
'60
'64
'68
'72
'76
'80
Year
Tanker Dimensions
Length
1700
1600
1500
1400
1300
1200
1100
LENGTH
Beam
300
200
100
BEAM
Draft & Depth
140
120
100
80
60
40
20
DEPTH
DRAFT
0
2
4
6
8
10
Hundred Thousand DWT
Bulk Carrier Dimensions
Length
1000
950
900
850
LENGTH
Beam
160
140
120
100
BEAM
Draft & Depth
100
90
80
70
60
50
40
DEPTH
DRAFT
50
60
80
100
120
140
160
Thousands DWT
Dry Cargo Ship Dimensions
Length
1100
1000
900
800
700
600
LENGTH
Beam
130
120
110
100
BEAM
Draft & Depth
100
80
60
40
20
DEPTH
DRAFT
0
10
20
30
40
50
Thousands DWT

Fig. 3.4

TABLE 3.3

DELIVERIES OF NEW OCEANGOING MERCHANT SHIPS (ALL TYPES) - 1966
1,000 GROSS TONS AND OVER
BY COUNTRY IN WHICH BUILT

Excludes ships built for operation on the Great Lakes; Inland Waterways; Armed Forces; and special types such as Tugs, Ferries, etc.

(Tonnage in Thousands)

Country	No.	Gross	DWT
U. S.	13	146	197
Denmark	21	434	722
Finland	22	100	131
France	14	310	445
W. Germany	60	971	1,516
Italy	16	492	748
Japan	243	5,885	9,556
Netherlands	17	245	382
Norway	32	383	607
Poland	27	207	267
Spain	25	274	395
Sweden	39	1,061	1,751
U. K.	58	951	1,397
U. S. S. R.	32	308	389
Yugoslavia	25	296	405
All Other	57	364	508
Total	701	12,427	19,416

Source: Marad

have an imbalance between steel fabrication, outfit, and erection capability in various yards and the industry as a whole. Many U. S. yards have improved their steel processing or fabrication capability and often, as a result, also increased their steel throughput capacity. On the other hand, assembly, outfit, and erection were left as they were, with the results of bottlenecks, facility underutilization, and decreased productivity.

The number of oceangoing merchant ships delivered by the industry in 1966 is shown in Table 3.3, which comprised only 12% of the 12,427 million gross tons delivered in the world during that year and 1% of the DWT. The low unit size of U.S. merchant ship construction is indicated by the 2% of the total number of ships built.

The general comments given in the previous paragraphs give an overall picture of the industry, but do not define its capacity in implicit terms. The available annual steel fabrication capacity of 0.73 million tons, for instance, is vastly in excess of the hull steel actually manufactured. While in tanker constructions the hull steel per gross ton has been reduced to less than 50% of that required 10 years ago, Fig. 3.5, a similar reduction has not been achieved in cargo or naval ship construction, which forms the bulk of the industry's sales. Over 85% of the productive manhours in the industry are spent in outfitting, which is historically a capital extensive activity. Another 6% are spent in cut-fitting and machinery shops. The industry employs 50% more workers than the Japanese shipbuilding industry, but, as Table 3.4 indicates, the ratio of staff to production worker is quite different. While the Japanese shipbuilding industry employees include 14% college graduates and 10%

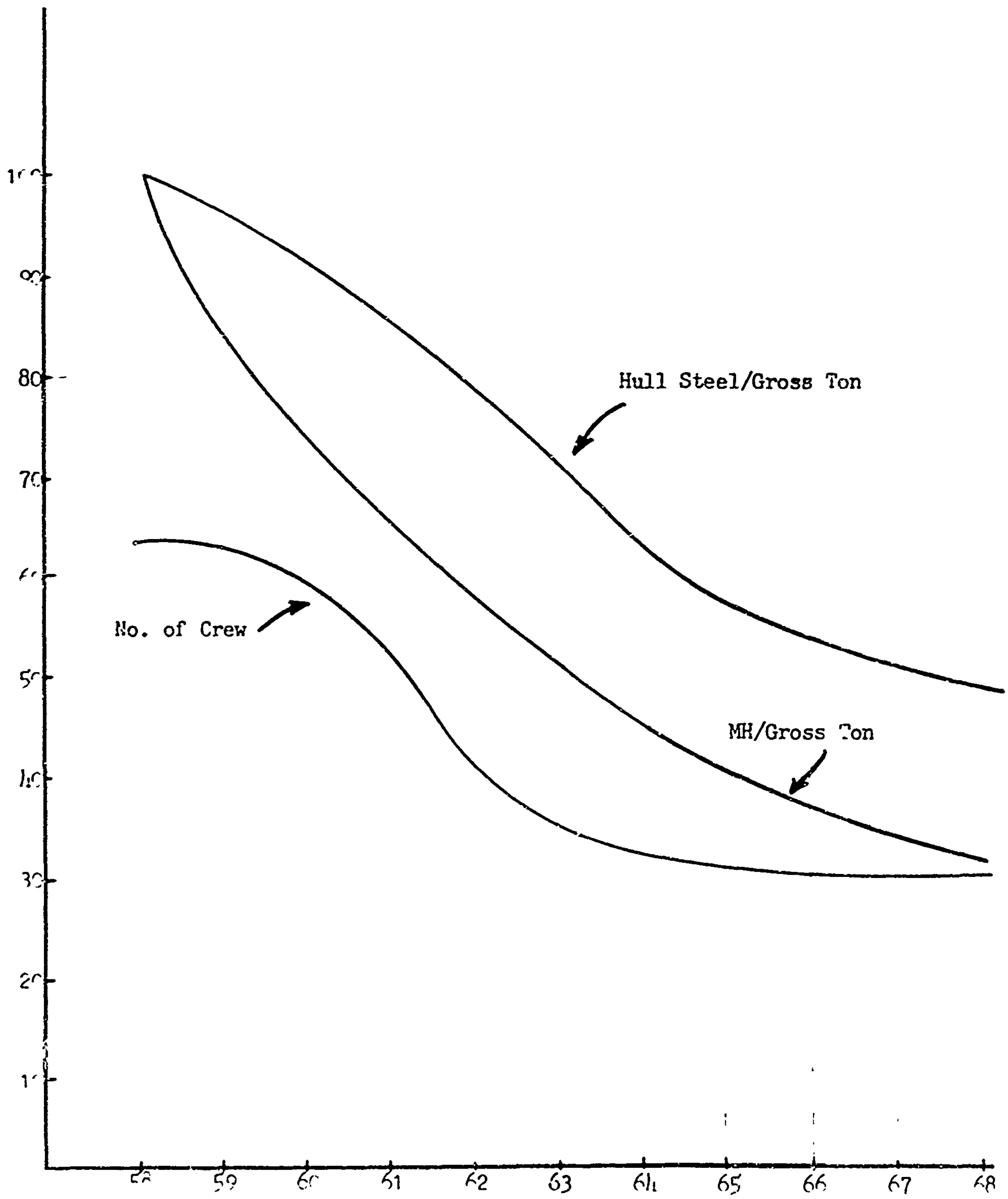


Fig. 3.5 Tanker Construction and Manning Trends

Table 3.4 Shipyard Personnel Breakdown

	Staff							Production			
	Technical			Administrative			Total			Total	Grand Total
	N.A	Eng.	Res.	Prod. Eng.	Managers/ Supervisors	Others		Skilled	Laborer		
U.S.	284	385	4700	265	2860	3400	11894	16,200	25,656	41,856	53,750
Japan	613	1533	4123	742	800	1469	9279	16,500	10,643	27,155	36,434

qualified engineers, the United States equivalent is 2.8% college graduates and 2% qualified engineers.

Considering the inherent capacity of the U.S. shipbuilding industry, over 1 million gross tons of shipping can be produced, in addition to the 40-50 naval ships built annually. To achieve this aim does not require major investments into new facilities, but primarily better use of existing resources in equipment and upgrading of manpower skills and qualifications. The industry lacks effective production and design engineering. This deficiency is only second to the ineffective and obsolete management, control, and inspection methods used.

Even if naval construction proceeds at current production rates and levels, the industry can be shown capable of producing over 80 additional merchant ships a year. An analysis of usage of ways and building docks shows that we could produce an additional annual output of:

8 Tankers 60-120,000 DWT

20 Container ships 15-25,000 DWT

10 Bulk carriers 25-60,000 DWT

42 Cargo ships 10-25,000 DWT,

assuming all available production resources are effectively applied.

4.) Economic Aspects of the U. S. Shipbuilding Industry

The cost of shipbuilding in the United States has been the subject of controversy over many years. While higher labor costs and some material cost differentials have been repeatedly quoted as the reasons for high U.S. ship production costs, these factors alone do not bear out all the differences. As a result, such reasons as:

- productivity per production manhour
- capital intensity
- make-or-buy ratio
- quality requirements and control
- management
- information system
- production engineering

must be included in any rational analysis of U.S. production costs.

Considering standard U.S. merchant ship construction, 52-61% of the shipyard costs are material, where the lower figure applies to small, high-class cargo ships, while higher range applies to large tankers or bulk carriers. If we divide shipyard costs into hull, outfit, and machinery, the breakdown is as follows:

	Material			Overhead and Labor		
	Hull	Outfit	Machinery	Hull	Outfit	Machinery
Tankers, large	20%	26%	16%	22%	10%	6%
Tankers, small	16%	27%	17%	20%	12%	8%
Low class cargo line	10%	26%	16%	20%	20%	8%
Container ship	12%	24%	20%	20%	16%	8%
High class cargo line	11%	29%	21%	15%	15%	9%

If we next consider coastal differences in costs of the factors of production, we derive, for a typical merchant ship:

	East Coast	West Coast	Great Lakes	Gulf Coast
Steel	100	104	102	101
Other Material	100	102	100	101
Labor	100	114	85	91
Overhead	100	97	100	97

As a result, we derive the relative cost of shipbuilding in the United States coastal areas as:

East Coast	West Coast	Gulf Coast	Great Lakes
100	106	96.5	95

These costs are affected by costs of materials, freight, labor rates, fringe benefits, utility costs, lost time, environmental effects, hiring costs, etc.

Considering the effect of multiple ship orders from a single yard on ship costs, we note from Fig. 4.1 that labor learning and large material orders result in much larger differential savings in ship production costs in the U.S. than abroad. Among the important reasons are the custom-made features of U.S. ships.

Considering the actual shipyard costs, Table 4.1 presents steel fabrication costs and requirements in a modern shipyard.

Shipbuilding costs have risen at a cumulative annual rate of 3.2% over the last 10 years (Fig. 4.2), while U.S. ship selling prices, which reached a low in 1961, are currently rising at about 3.4% per year (Fig. 4.3).

The shipbuilding industry had sales of $2.27M in 1966, reaching $2.48M in 1967. The various sources of funds are indicated in Table 4.2

Fig. 4.1 RELATIONSHIP OF MATERIAL LABOR AND OVERHEAD TO FOREIGN AND U.S. SHIPYARD MULTIPLE SHIP COST

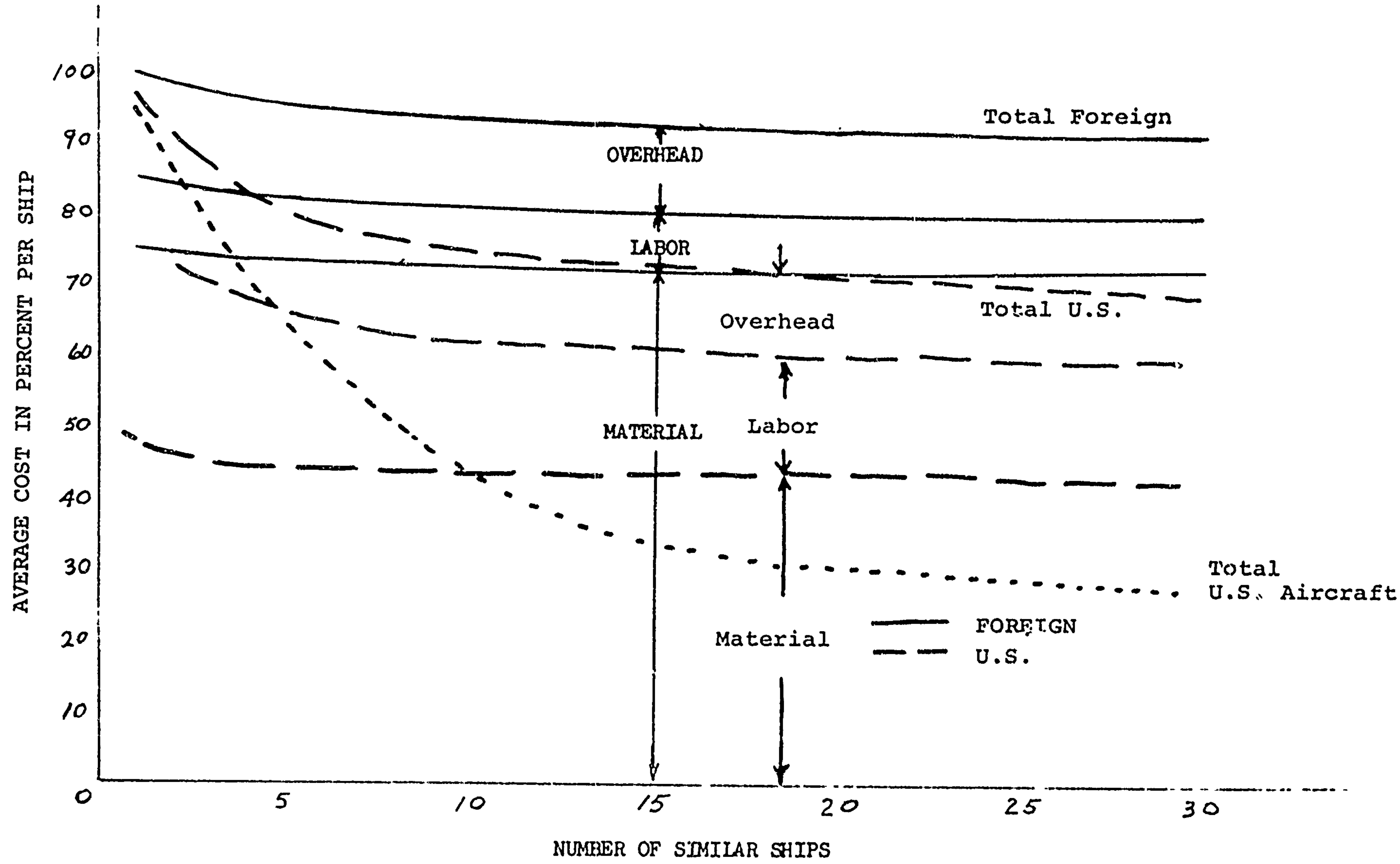


Table 4.1 Modern Steel Fabrication Costs and Requirements

Steel Prefabrication:

Shot blasting	0.6 cents/ft^2
Painting (priming one coat, both sides)	2.0 cents/ft^2
Preheating	0.2 cents/ft^2
Total steel prefabrication costs	2.8 cents/ft^2

(based on a 10,000 tons/month throughput and a fully automated prefabrication line)

Steel Fabrication:

Flame cutting (average of contour and straight cutting, all thicknesses)	8 cents/linear ft
Edge milling (stack cutting of 90° edges)	1 cent/linear ft
Edge milling (single plate, special edge preparation)	5 cents/linear ft

Plate Storage Yard:

5-7 ft^2 per ton of stored steel

Prefabricated and Processed Steel Yard Storage:

80 ft^2 per ton of stored steel

Fig. 4.2

INDEX OF ESTIMATED SHIPBUILDING COST
IN THE UNITED STATES
(January 1, 1939 = 100)

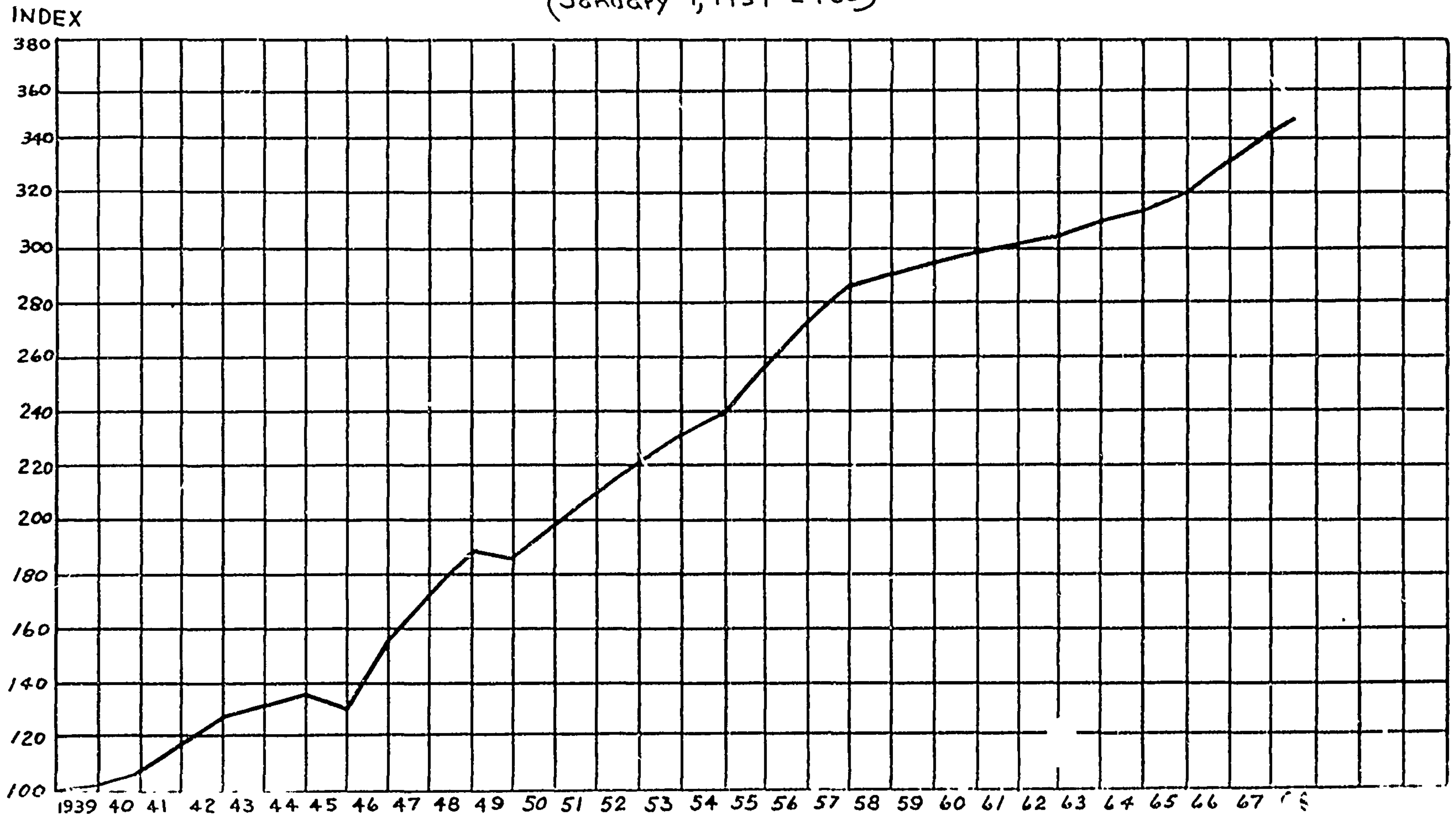


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Fig. 4.3

New Ship Selling Price Index
(October 1957 = 100)

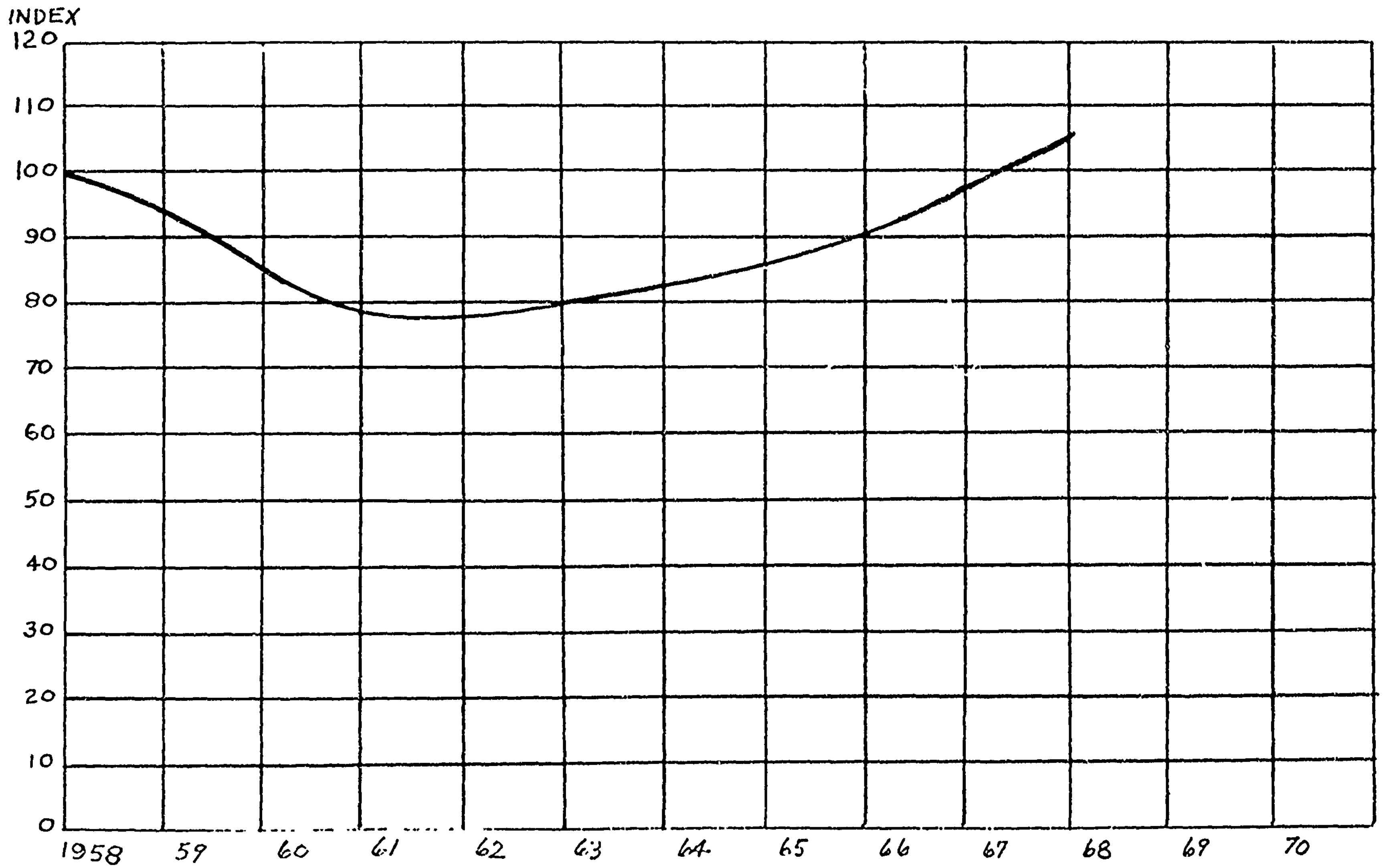

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Table 4.2 SOURCE OF FUNDS AVAILABLE FOR U.S. SHIPBUILDING, CONVERSION AND REPAIR

FISCAL YEAR 1966 ESTIMATED IN MILLIONS

	New Construction And Conversion				Ship Repair			
	Pvt Yards	Gov't. Yards	GFE Etc.	Total	Pvt Yards	Gov't. Yards	Total	Grand Total
Navy	1151.2	203.0	519.1	1873.3	349.7	511.0	860.7	2734.0
MarAd	262.2	--	4.9	267.1	38.2	--	38.2	305.3
Other Gov't.	77.5	9.9	2.1	89.5	27.2	6.6	33.8	123.3
Private	41.5	--	--	41.5	196.0	--	196.0	237.5
Total	1532.4	212.9	526.1	2271.4	611.1	517.6	1128.7	3400.1

Considering the labor costs, it is noted that while the take-home pay of the U.S. shipyard worker is nearly 4 times that of his Japanese counterpart, the actual cost of labor differential is much smaller, as indicated in Table 4.3. These figures show that real U.S. labor costs are only 33% above those of Sweden, for example. An even more important consideration is the actual annual increase in real labor costs. If current trends continue, then U.S. shipyard labor costs will equal those of most major shipbuilding countries before 1980. Under such circumstances, protective measures and subsidies may not be justifiable and only a modern, well-managed U.S. ship production industry may then be able to maintain a position of importance.

To consider investment policies to assure future capability, it may be interesting to compare the extent and distribution of U.S. versus Japanese investments into ship production facilities (Fig. 4.4). Not only is the total dollar investment differential astounding, but the distribution of investment is rather curious, as the bulk of U.S. investments were made in steel processing, storage and handling equipment.

Table 4.3

COMPARISON OF SHIPBUILDING HOURLY EARNINGS ($/HR)

1966

	Take-Home Pay	Including Fringe Benefits	Annual Increase
United States	3.33	3.85	4.2%
Sweden	1.79	2.82	7. %
Germany	1.25	1.64	6.5%
United Kingdom	1.20	1.78	7. %
Netherlands	1.07	1.71	6. %
Japan	.85	1.54	9.2%

Table 4.4 TOTAL INVESTMENT ON SHIPYARD FACILITIES 1956/1965

Items	Japanese Shipyards 1956/1965		U.S. Shipyards 1956/1965	
	Investment M-$	%	Investment M-$	%
Berths	64.4	8.3	2.2	2.0
Docks and Ways	38.8	5.0	22.0	20.0
Quay	21.2	2.7	8.2	6.6
Transportation Facilities	87.6	11.3	20.0	18.3
Hull Processing and Assembling Facilities	95.6	12.3	28.8	26.4
Power Source	26.4	3.4	6.1	5.6
Machinery Manufacturing Facilities	198.8	25.6	4.2	3.8
Indirect Facilities	132.8	17.1	11.1	10.2
Miscellaneous	111.6	14.3	7.0	6.4
TOTAL	777.2	100.0	109.6	100.0

5.) <u>Productivity of the U. S. Shipbuilding Industry and Comparison with World Shipbuilding:</u>

Shipbuilding productivity is an elusive concept which means something different to the many various parties concerned. While the shipyard owner may be concerned with return on invested capital, shipyard managers in added value or throughput per manhour, the government in total output or total production per man, many additional criteria could be applied. To quote just a few measures of productivity or performance:

(1) total output or sales or cash flow

(2) discounted cash flow

(3) return on capital

(4) output per man (manhour)

(5) capital recovery factor

(6) total added value

(7) net profit

(8) sales or output/subsidy

(9) other.

As a result, any discussion of productivity tends invariably towards a parochial point of view. In this study we will simply attempt to quote some facts and estimates for comparative purposes to establish the relative effectiveness of U.S. shipbuilding.

The total amount of Marad (subsidized) shipbuilding awards, 1958-1966, are presented in Table 5.1. Ship construction differential subsidy, which was negligible until 1955, had risen to $120-135 M by 1963-1964, and is currently maintained at a level of just under $100 M. A summary of U.S. private shipbuilding is presented in Table 5.2 which indicates that, although over 44 commercial and 100 naval ships are under construction at any one time, only 16-18 commercial and about 20 naval ships are delivered per year. This ship-under-construction to delivery rate, furthermore, has not changed appreciably over the last 10-20 years. It indicates that a commercial ship may spend as much as three years under construction while a naval ship averages 4-5 years. While this conclusion is admittedly simplified and other factors contribute to the large discrepancies between the number of ships under construction and those delivered during any period of time, the results still indicate that the average high-class merchant ship spends over twice as much time in a U.S. shipyard than a comparable ship requires in an average modern foreign shipyard. Considering the capital invested per ship, it can be easily shown that the additional construction residence time easily adds 5-6% to the cost of the ship. If we add to this figure the effect of the complementary long and extensive material stocking which amounts to 4-6 months of supplies for the average U.S. shipyard compared to 0.5-2 months in an equivalent foreign yard, the total capital cost of excess ship and material inventory time accounts for 8-9% of ship cost. Similar comparisons in the construction of naval ships are not possible as combatant and war ships vary extensively in detail.

Considering Table 5.1, it is noted that the cost of construction of a U.S. commercial ship is generally 2.22 times that of an equivalent foreign ship (excluding national defense features).

TABLE 5.1

SUBSIDIZED SHIPBUILDING CONTRACTS AWARDED IN PERIOD JANUARY 1, 1958 - JUNE 30, 1966

Contract Date	No. Ships	Design	Owner-Contractor	1 Ship Price incl. Nat. Def.	Commercial Ship Contract	Nat. Defense Contract	Total Contract Price	Foreign Cost 1 Ship
2-13-58	2	C3-S-38a	Export-NY Ship	$11,420,983	$22,539,016	$302,950	$22,841,966	$5,850,000
2-13-58	2	C3-S-38a	Export-Nat. Steel	11,754,501	23,384,132	124,870	23,509,002(f)	5,850,000
1-28-58	5	C3-S-37a	Lykes-Ingalls	9,636,027	48,050,385	129,750	48,180,135	5,330,000
2-14-58	2	C3-S-33a	Mooremac-Sun	10,621,943	20,982,082	261,804	21,243,886	5,590,000
2-14-58	2	C3-S-33a	Mooremac-Todd	11,012,421	21,874,588	150,254	22,024,842	5,590,000
2-28-58	2	C4-S-1q	APL-Beth. Pac.	14,566,000	28,812,000	320,000	29,132,000	7,275,000
	15		TOTAL F. Y. 1958		$165,642,203	$1,289,628	$166,931,831	
10- 3-58	4	C3-S-37a	Lykes-Beth. S. P.	9,172,000	36,464,640	223,640	36,688,000	5,050,000
1- 2-59	3	C3-S-33a	Mooremac-Sun	10,065,514	29,954,352	242,190	30,196,542	5,250,000
3-17-59	4	C3-S-46a	Export-Nat. Steel	11,035,520	43,595,175	546,904	44,142,079(f)	5,555,000
5-19-59	3	C3-S-43a	Miss.-Avondale	9,802,718	28,773,000	635,154	29,408,154	4,990,000
	14		TOTAL F. Y. 1959		$138,787,167	$1,647,608	$140,434,775	
8- 5-59	3	C4-S-1s	Amer. Mail-Todd	12,005,594	35,775,167	241,617	36,016,784	6,150,000
9-22-59	2	C4-S-1t	PFEL-Beth. Pac.	13,673,000	27,132,000	214,000	27,346,000	6,850,000
2-26-60	3	C4-S1-49a	Grace-Beth. S. P.	17,543,000	52,483,980	147,000	52,630,980(f)	8,450,000
2-29-60	4	C4-S-1u	States-Newport Ns.	11,210,250	44,283,460	557,540	44,841,000	6,030,000
6-21-60	1	C3-S-33a	Mooremac-Sun	9,439,615	9,382,532	57,083	9,439,615	4,580,000
	13		TOTAL F. Y. 1960		$169,057,139	$1,217,240	$170,274,379	
9-13-60	4	C3-S-37b	Lykes-Beth. S. P.	9,059,600	36,022,400	216,000	36,238,400(f)	4,229,000
9-22-60	6	C4-S-58a	Farrell-Ingalls	10,453,871	61,614,846	1,108,380	62,723,226(f)	5,289,000
9- 7-60	5	C4-S-57a	U. S. L.-New. News	10,573,255	52,476,275	390,000	52,866,275(f)	5,146,000
1-30-61	4	C3-S-46b	Export-Sun	8,770,000	34,852,000	228,000	35,080,000(f)	4,525,000
1-11-61	6	C4-S-57a	U. S. L.-Beth. Q.	9,797,000	58,218,000	564,000	58,782,000(f)	5,150,000
1-27-61	4	C3-S-37c	Lykes-Beth. S. P.	8,539,000	33,940,000	216,000	34,156,000(f)	4,170,000
2-28-61	2	C4-S-1u	States-Nat. Steel	11,110,424	22,078,274	142,574	22,220,848(f)	5,770,000
	31		TOTAL F. Y. 1961		$299,201,795	$2,864,954	$302,066,749	

TABLE 5.1

Table 5.1 (continued)

11-29-61	4	C3-S-37c	Lykes-Avondale	8,062,000	32,072,000	176,000	32,248,000(f)	4,049,000
11-29-61	2	C3-S-37d	G.&S.A.-Avondale	8,200,000	16,290,000	110,000	16,400,000(f)	4,201,000
2-1-62	1	C4-S1-49a	Grace-Beth. S.P.	17,957,000	17,907,000	50,000	17,957,000(f)	8,896,000
6-29-62	6	C4-S-60a	Mooremac-Ingalls	10,375,000	62,174,628	75,372	62,250,000(f)	5,266,000
	13		TOTAL F.Y. 1962.		$128,443,628	$411,372	$128,855,000	
10-10-62	5	C4-S-64a	U.S.L.-Sun	10,590,000	52,859,500	90,500	52,950,000(f)	5,430,000
12-27-62	2	C4-S-1sa	Am. Mail-Nat. Steel	11,346,000	22,556,000	136,000	22,692,000(f)	5,344,000
4-4-63	4	C4-S-66a	Lykes-Avondale	10,039,913	40,156,292	3,360	40,159,652(f)	5,037,000
6-14-63	4	C4-S-65a	Grace-Sun	13,150,000	52,580,000	20,000	52,600,000(f)	6,034,000
6-27-63	3	C4-S-1qa	APL-Nat. Steel	12,399,000	37,134 000	63,000	37,197,000(f)	5,623,000
	18		TOTAL F.Y. 1963		$205,285,792	$312,860	$205,598,652	
8-2-63	3	C3-S-37d	G.&S.A.-Avondale	8,613,013	25,680,039	159,000	25,839,039(f)	3,944,000
11-21-63	4	C4-S-66a	Lykes-Avondale	10,329,013	41,312,692	3,360	41,316,052(f)	4,642,000
1-10-64	2	C4-S-65a	Grace-Sun	12,625,000	25,240,000	10,000	25,250,000(f)	5,984,000
4-24-64	2	C4-S-64b	Prudential-Beth. SP	10,797,000	21,462,000	132,000	21,594,000(f)	4,992,000
6-26-64	4	C4-S-66a	Lykes-Avondale	10,499,999	41,996,636	3,360	41,999,996(f)	4,832,000
	15		TOTAL F.Y. 1964		$155,691,367	$307,720	$155,999,087	
12-9-64	5	C4-S-68a	U.S.L.-Sun	12,190,000	60,950,000	None	60,950,000(f)	5,743,000
12-31-64	4	C4-S-69a	APL-Ingalls	13,715,590	54,824,220	38,140	54,862,360(f)	6,302,000
6-28-65	5	C3-S-76a	Delta-Ingalls	10,494,180	52,143,550	327,350	52,470,900(f)	4,870,000
	14		TOTAL F.Y. 1965		$167,917,770	$365,490	$168,283,260	
9-22-65	1	C4-S-69a	APL-Ingalls	13,189,265	13,179,730	9,535	13,189,265(f)	6,247,000
11-30-65	3	C4-S-73a	AEIL-Bath	12,923,000	38,769,000	21,000	38,790,000(f)	5,913,000
5-20-66	5	C4-S-69b	States S.S.-Avon.	14,673,612	72,258,505	665,875	73,368,060(f)	6,540,000
6-9-66	3	C5-S-75a	Am. Mail-New. Ns.	16,260,450	48,180,000	135,000	48,765,950(f)	7,227,000
6-9-66	1	C5-S-75b	PFEL-New. News	16,844,000	16,665,000	45,000	16,844,000(f)	7,832,000
6-30-66	4	C5-S-78a	Mooremac-Ingalls	15,856,820	62,438,076	843,944	63,479,090	NA
	17		TOTAL F.Y. 1966		$251,490,311	$1,720,354	$254,436,365	
GRAND TOTAL	141				$1,681,517,172	$10,137,226	$1,692,880,098	

(f) Fixed price

U.S. PRIVATE SHIPBUILDING SUMMARY

Gross and deadweight tons for commercial vessels, light displacement tons for naval vessels. Includes Alaska and Hawaii. Covers steel self-propelled vessels 1000 tons and over

ITEM	1964		1965		First Quarter 1966		Second Quarter 1966	
	No.	Gross Tons D/W Tons	No.	Gross Tons D/W Tons	No.	Gross Tons D/W Tons	No.	Gross Tons D/W Tons
COMMERCIAL VESSELS								
Under Construction First Day	45	517, 390 649, 711	47	550, 400 650, 017	45	513, 000 579, 881	44	512, 700 563, 117
Contracted For	18	244, 200 289, 895	14	142, 800 164, 380	1	20, 900 10, 950	13	187, 100 224, 500
Launched	20	239, 200 318, 395	17	221, 100 290, 875	2	24, 300 27, 317	2	22, 800 27, 338
Delivered	16	223, 790 289, 589	16	180, 200 234, 516	2	21, 200 27, 714	6	68, 300 82, 110
Under Construction Last Day	47	550, 400[1] 650, 017	45	513, 000 579, 881	44	512, 700 563, 117	51	631, 500 705, 557
NAVAL VESSELS		1964		1965		First Quarter		April & May 1966
Under Construction First Day[2]	83	450, 254	100	535, 931	105	571, 957	108	606, 564
Contracted For	39	194, 968	23	158, 429	5	43, 950	1	11, 300
Launched	22	132, 828	15	102, 287	6	28, 815	6	26, 084
Delivered	21	107, 970	18	122, 403	2	9, 343	3	18, 740
Under Construction Last Day	101	537, 252	105	571, 957	108	606, 564	106	599, 124

1 Revised Tonnage; 2 Excludes vessels cancelled during year.

TABLE 5.2

As only 39-48% of the U.S. ship building costs are labor, overhead, and profit, the 2.22 cost factor is difficult to explain on the basis of labor cost differential alone.

Considering a typical cargo ship costing $12 M in the U.S., the equivalent ship built in the low-cost foreign yard would be priced at $5.48 M.

The cost breakdown in the two yards then looks as follows:

	U.S.	Foreign
Material	$ 7.05 M	$ 4.32 M
Labor	3.64 M	0.72 M
Overhead	0.71 M	0.18 M
Profit	0.60 M	0.26 M
	$12.00 M	$ 5.48 M

While the percentages vary somewhat depending on the particular U.S. yard and the ratio of inventory and other capital charges applied to overhead, the general relationship holds. This comparison indicates that labor costs outweigh by far labor rate differential presented in Table 4.3. In fact, assuming an equal number of manhours were spend in the U.S. yard, the labor costs should only be $1.8 M. Even assuming that some of the fringe benefits are included in the U.S. overhead rate, the combined labor-overhead rate should only amount to $2.25 M instead of $4.35 M. In fact, considering manhours spent, it is easily established that efficient foreign shipyards only require 45-60% of the manhours to build an equivalent ship. The equivalency of foreign ship construction is often questioned. Though it may be true that U.S. ships are 'better' built, the comparisons are always made for ships built under the same construction, classification, and often safety rules. Furthermore, statistical data does not indicate any discrepancy in the failure rate or other deficiencies of foreign versus U.S. built ships.

Another important consideration is the large cost differential in materials bought for shipsets of identically specified components. While most U.S. manufactured goods compete effectively in world trade, it is intereating to note that ship components indicate large cost differentials, though often produced by efficient U.S. exporters of capital goods. It is estimated that a large factor in the material and overhead differential is accounted for by larger inventory costs. It may also be argued that, while the U.S. Government may be obliged to support the continued availability and capability of U.S. shipbuilding industry and labor, a lesser justification may exist for the indirect support of U.S. shipbuilding material manufacturers. It can be easily shown that if the U.S. shipbuilding industry were permitted to purchase material competetively without regard to origin and if inventory and other related overhead charges were reduced to that of foreign yards (which have inherently larger investments), the cost differential of commercial shipbuilding in the U.S. could be reduced to 1-1:52 or a total construction subsidy of 34.2% instead of 55%. Table 5.3 shows that the Federal Government had construction obligations for over 295 ships in 1966, with an estimated cost of over $4,178. Considering that ample funds are available to

TABLE 5.3

STATUS OF SUBSIDIZED SHIP REPLACEMENT PROGRAMS AS OF JULY 1, 1966

	Construction Obligations					Delivered		On Order	
Operator	F	P	C	T	Cost [1]	No.	Price	No.	Price [2]
Amer. Export & Isbrandtsen	38	3	-	41	$644	12F	$125.5	3F	$38.8
American Mail	8	-	-	8	107	5F	58.7	3F	48.7
Amer. Pres.	22	2/3	-	24/25	521	4F	66.3	5F	68.0
Delta	10/13	-	3/0	13	143	3F	29.4	5F	52.5
Farrell	21	-	-	21	268	6F	62.7	-	-
Grace	13	-	9	22	387	6C 1F	116.1 12.6	5F	65.2
Gulf & So. American	5	-	-	5	42	5F	42.2		
Lykes	50	-	-	50	570	25F	219.8	8F	83.0
MorMac	39	-	2	41	463	2C 14F	48.8 145.0	4F	65.1
Oceanic	3	-	-	3	34	-	-	-	-
Pac. Far East	10	-	-	10	138	2F	27.3	1F	16.8
Prudential	5	-	-	5	62	2F	21.6	-	-
States	13	-	-	13	185	6F	67.0	5F	73.4
U. S. Lines	38	1	-	39	614	16F	164.6	5F	61.0
TOTALS	275/278	6/7	14/11	295/296	$4,178	8C 101F 109T	$164.9 1042.7 $1207.6	44F 44T	$572.5 $572.5

KEY: F = freighter
P = passenger
C = combination passenger-cargo
T = total
1/ = estimated cost in millions of dollars
2/ = original contract price in millions of dollars

subsidized and unsubsidized owners in reserve funds to take advantage of any subsidized increase in commercial ship construction, it can be easily shown that a substantial reduction in unit subsidy requirement may result in a larger number of ships on order. As the industry is quite capable of handling a 3-500% increase in commercial ship construction without affecting naval shipbuilding programs, the resulting industry productivity can be expected to increase. Such an approach may also stimulate serial construction of ships with learning (including material) benefits of up to 26%.

6.) Summary and Conclusions:

In summary, it can be said that U.S. shipbuilding cost differentials can be reduced to just 20-24% above that of low-cost foreign producers, if:

(1) productivity or manhour use is equated to foreign requirements,

(2) serial construction of ships in sets of not less than 12 is imposed, all built in one yard,

(3) material can be bought without reference to origin,

(4) inventory size and cost are reduced to no more than 1-2 month throughput equivalents,

(5) advantage is taken of lower U.S. capital costs,

(6) effective use of modern production, production engineering, planning and management methods,

(7) methods of design and production are maintained up to date by effective research and analysis.

APPENDIX A

HIGHLIGHTS OF CONSTRUCTION DIFFERENTIAL SUBSIDY LAWS

Sec. 501 (a). Any citizen of the United States may make application to the Commission for a construction differential subsidy to aid in the construction of a new vessel to be used in the foreign commerce of the United States. No such application shall be approved by the Commission unless it determines that (1) the plans and specifications call for a new vessel which will meet the requirements of the foreign commerce of the United States, will aid in the promotion and development of such commerce, and be suitable for use by the United States for national defense or military purposes in time of war or national emergency; (2) the applicant possesses the ability, experience, financial resources, and other qualifications necessary to enable it to operate and maintain the proposed new vessel, and (3) the granting of the aid applied for is reasonably calculated to replace wornout or obsolete tonnage with new and modern ships, or otherwise to carry out effectively the purposes and policy of this Act. The contract of sale, and the mortgage given to secure the payment of the unpaid balance of the purchase price shall not restrict the lawful or proper use or operation of the vessel except to the extent expressly required by law.

(b) Plans of vessels submitted to Navy Department. Secretary of Navy to certify approval.

(c) Subsidy for reconstructing and reconditioning vessel. Reconstructing and reconditioning subsidies only in exceptional cases.

Sec. 502 (a). If the Secretary of the Navy certifies his approval under section 501(b) of this Act, and the Commission approves the application, it may secure, on behalf of the applicant, bids for the construction of the proposed vessel according to the approved plans and specifications. If the bid of the shipbuilder who is the lowest responsible bidder is determined by the Commission to be fair and reasonable, the Commission may approve such bid, and if such approved bid is accepted by the applicant, the Commission is authorized to enter into a contract with the successful bidder for the construction, outfitting, and equipment of the proposed vessel, and for the payment by the Commission to the shipbuilder, on terms to be agreed upon in the contract, of the contract price of the vessel, out of the construction fund hereinbefore referred to, or out of other available funds. Concurrently with entering into such contract with the shipbuilder, the Commission is authorized to enter into a contract with the applicant for the purchase by him of such vessel upon its completion, at a price corresponding to the estimated cost, as determined by the Commission pursuant to the provisions of this Act, of building such vessel in a foreign shipyard.

(b) The amount of the reduction in selling price which is herein termed "construction differential subsidy" may equal, but not exceed, the excess of the bid of the shipbuilder constructing the proposed vessel (excluding the cost of any features incorporated in the vessel for national defense uses, which shall be paid by the Secretary in addition to the subsidy), over the fair and reasonable estimate of cost, as determined by the

Secretary, of the construction of the proposed vessel if it were constructed under similar plans and specifications (excluding national defense features as above provided) in a foreign shipbuilding center which is deemed by the Secretary to furnish a fair and representative example for the determination of the estimated foreign cost of construction of vessels of the type proposed to be constructed. The construction differential approved and paid by the Secretary shall not exceed 55 per centum of the construction cost of the vessel, except that in the case of reconstruction or reconditioning of a passenger vessel having the tonnage, speed, passenger accommodations and other characteristics set forth in section 503 of this Act, the construction differential approved and paid shall not exceed 60 per centum of the reconstruction or reconditioning cost (excluding the cost of national defense features as above provided): Provided, however, That after June 30, 1966, the construction differential approved by the Secretary shall not exceed in the case of the construction, reconstruction or reconditioning of any vessel, 50 per centum of such cost. When the Secretary finds that the construction differential in any case exceeds the foregoing applicable percentage of such cost, the Secretary may negotiate and contract on behalf of the applicant to construct, reconstruct, or recondition such vessel in a domestic shipyard at a cost which will reduce the construction differential to such applicable percentages or less. In the event that the Secretary has reason to believe that the bidding in any instance is collusive, he shall report all of the evidence on which he acted (1) to the Attorney General of the United States, and (2) to the President of the Senate and to the Speaker of the House of Representatives if the Congress shall be in session or if the Congress shall not be in session, then to the Secretary of the Senate and Clerk of the House, respectively.

(c) In such contract between the applicant and the Commission, the applicant shall be required to make cash payments to the Commission of not less than 25 per centum of the price at which the vessel is sold to the applicant. The cash payments shall be made at the time and in the same proportion as provided for the payments on account of the construction cost in the contract, between the shipbuilder and the Commission. The applicant shall pay, not less frequently than annually, interest at the rate of $3\frac{1}{2}$ per centum per annum on those portions of the Commission's payments as made to the shipbuilder which are chargeable to the applicant's purchase price of the vessel (after deduction of the applicant's cash payments). The balance of such purchase price shall be paid by the applicant, within twenty-five years after delivery of the vessel and in not to exceed twenty-five equal annual installments, the first of which shall be payable one year after the delivery of the vessel by the Commission to the applicant. Interest at the rate of $3\frac{1}{2}$ per centum per annum shall be paid on all such installments of the purchase price remaining unpaid.

(Subsection (d) was repealed by section 2(a) of Public Law 87-877 (76 Stat. 1200), approved October 24, 1962, which contains the following proviso: "Provided, however, that the repeal of subsection (d) of section 502 of the Merchant Marine Act, 1936, shall not be effective with respect to contracts for new ship construction under title V of said Act awarded on the basis of bids opened prior to the date of enactment of this Act.)

(e) If no bids are received for the construction, outfitting, of equipping of such vessel, or if it appears to the Commission that the bids received from privately owned shipyards of the United States are collusive, excessive, or unreasonable, and if the applicant agrees to purchase said vessel as provided in this section, then, to provide employment for citizens of the United States, the Commission may have such vessel constructed, outfitted, or equipped at not in excess of the actual cost thereof in a navy yard of the United States under such regulations as may be promulgated by the Secretary of the Navy and the Commission. In such event the Commission is authorized to pay for any such vessel so constructed from its construction fund. The Commission is authorized to sell any vessel so constructed, outfitted, or equipped in a navy yard to an applicant for the fair and reasonable value thereof, but at not less than the cost thereof less the equivalent to the construction-differential subsidy determined as provided by subsection (b), such sale to be in accordance with all of the provisions of this title.

(f) The Secretary of Commerce, with the advice of and in coordination with the Secretary of the Navy, shall, at least once each year, as required for purposes of this Act, survey the existing privately owned shipyards capable of merchant ship construction, or review available data on such shipyards if deemed adequate, to determine whether their capabilities for merchant ship construction, including facilities and skilled personnel, provide an adequate mobilization base at strategic points for purposes of national defense and national emergency. The Secretary of Commerce, in connection with ship construction, reconstruction, reconditioning, or remodeling under title VII and section 509 and the Federal Maritime Board, in connection with ship construction, reconstruction, or reconditioning under title V (except section 509), upon a basis of a funding that the award of the proposed construction, reconstruction, reconditioning, or remodeling work will remedy an existing or impending inadequacy in such mobilization base as to the capabilities and capacities of a shipyard or shipyards at a strategic point, and after taking into consideration the benefits accruing from standardized construction, the conditions of unemployment, and the needs and reasonable requirements of all shipyards may allocate such construction, reconstruction, reconditioning, or remodeling to such yard or yards in such manner as it may be determined to be fair, just, and reasonable to all sections of the country, subject to the provisions of this subsection. In the allocation of construction work to such yards as herein provided, the Commission may, after first obtaining competitive bids for such work in compliance with the provisions of this Act, negotiate with the bidders and with other shipbuilders concerning the terms and conditions of any contract for such work, and is authorized to enter into such contract at a price deemed by the Commission to be fair and reasonable. Any contract entered into by the Commission under the provisions of this subsection shall be subject to all of the terms and conditions of this Act, excepting those pertaining to the awarding of contracts to the lowest bidder which are inconsistent with the provisions of this subsection. In the event that a contract is made providing for a price in excess of the lowest responsible bid which otherwise would be accepted, such excess shall be paid by the Commission as a part of the cost of national defense, and shall not be considered as a part of the construction-differential subsidy. In the event that a contract is made providing for a price lower than the lowest responsible bid which otherwise would be accepted, the construction-differential subsidy shall be computed on the contract price in lieu of such bid.

If, as a result of allocation under this subsection, the applicant insurs expenses for inspection and supervision of the vessel during construction and for the delivery voyage of the vessel in excess of the estimated expenses for the same services that he would have incurred if the vessel had been constructed by the lowest responsible bidder the Secretary of Commerce (with respect to construction under title V, except section 509) shall reimburse the applicant for such excess, less one-half of any gross income the applicant receives that is allocable to the delivery voyage minus one-half of the extra expenses incurred to produce such gross income, and such reimbursement shall not be considered part of the construction-differential subsidy: Provided, That no interest shall be paid on any refund authorized under this Act. If the vessel is constructed under section 509 the Secretary of Commerce shall reduce the price of the vessel by such excess, less one-half of any gross income (minus one-half of the extra expenses incurred to produce such gross income) the applicant receives that is allocable to the delivery voyage. In the case of a vessel that is not to receive operating-differential subsidy, the delivery voyage shall be deemed terminated at the port where the vessel begins loading. In the case of a vessel that is to received operating-differential subsidy, the delivery voyage shall be deemed terminated when the vessel begins loading at a United States port on any essential service of the operator. In either case, however, the vessel owner shall not be compensated for excess vessel delivery costs in an amount greater than the expenses that would have been incurred in delivering the vessel from the shipyard at which it was built to the shipyard of the lowest responsible bidder. If as a result of such allocation, the expenses the applicant incurs with respect to such services are less than the expenses he would have incurred for such services if the vessel had been constructed by the lowest responsible bidder, the applicant shall pay to the Secretary of Commerce an amount equal to such reduction and, if the vessel was built with the aid of construction-differential subsidy, such payment shall not be considered a reduction of the construction-differential subsidy.

(g) Vessel acquired by commission-sale to applicant. Eligible for operating-differential subsidy.

Sec. 503. Subsidized vessels to be documented under laws of U.S. Delivery with bill of sale - warranty against liens. Documentation to be for 25 years and while purchase price of interest owing. First preferred mortgage by applicant to secure payments.

Sec. 504. Construction financed by applicant. Interests of U.S. protected. Documentation.

Sec. 505 (a). All construction in respect of which a construction-differential subsidy is allowed under this title shall be performed in a shipyard within the continental limits of the United States as the result of competitive bidding, after due advertisement, with the right reserved to the applicant to reject, and in the Commission to disapprove, any or all bids. In all such construction the shipbuilder, subcontractors, materialmen, or suppliers shall use, so far as practicable, only articles, materials, and supplies of the growth, production, or manufacture of the United States as defined in paragraph K of section 401 of the Tariff Act of 1930. No shipbuilder shall be deemed a responsible bidder unless he possesses the ability, experience, financial resources, equipment, and other qualifications necessary properly to perform the proposed contract. Each bid submitted to the Commission shall be accompanied by all detailed estimates upon which it is based. The Commission may require that the bids of any subcontractors, or other pertinent data, accompany such bid. All such bids and data relating thereto shall be kept permanently on file. For the purposes of this subsection, the term "continental limits of the United States" includes the States of Alaska and Hawaii.

(b) Requirements for shipbuilder's contract. Report. Excess profits. No subdivision of contract or subcontract for evasion. Books, records. Subject to inspection and audit - premises subject to inspection. Applicable to subcontracts. Exception. Contracts for scientific equipment.

(c) Determination of shipbuilder's profits - salaries exceeding $25,000 per annum excluded from building costs - scrutiny costs, and expenses by Commission.

(d) Utilization of Treasury employees.

(e) Shipbuilder's refusal of contractual requirements.

Sec. 506. Subsidized vessels to be operated in foreign trade, round voyages intercoastal ports, island possessions. Temporary transfer of vessel to domestic trade. No operating subsidy during transfer.

Sec. 507. Replacement of old vessels - purchase by Commission - valuation. Purchase price applied against construction cost of new vessel. Bond by owner. Vessel documented for at least 10 years.

Sec. 508. Scrapping or sale of vessels of insufficient value for commercial or military operation. Purchaser to give bond.

Sec. 509. Construction for domestic trade. No construction subsidy. Applicant to pay percentage of cost. Balance in 25 annual installments. Secured by preferred mortgage.

Sec. 510 (a). "Obsolete vessels" defined. Merchant Marine Act 1936 amendment. "New vessel" defined.

(b) Obsolete vessels, trade-in.

(c) Utility value of new vessel. Tonnage ratio.

(d) Allowance. Determination of amount.

(e) Income taxes - no gain to be recognized.

(f) Annual report.

(g) Use of obsolete vessels and of laid-up fleet restricted.

(Subsection (h) expired by its terms on July 1, 1958.)

(i) Vessel exchange program,extension. Valuation of vessels. Tanker vessels.

(j) National Defense reserve fleet.

Sec. 511 (a). "New vessel" defined. Documentation.

(b) Authority for establishment of construction reserve fund for the construction or acquisition of new vessels.

(c) Taxes. Recognition of gain, etc.

(d) Determination of gain, etc.

(e) Deposits and withdrawals order, set-off, etc.

(f) Certain deposits not to be considered an accumulation of earnings or profits.

(g) Tax benefits. Conditions.

(h) Commission authorized to grant extensions of time.

(i) Conditions under which deposits taxable.

(j) Assessment and collection of deficiency.

(k) Date of application of section.

(l) Construction or acquisition of vessel by corporation.

(m) Definitions.

(n) Definitions.

(o) Great Lakes, etc.

APPENDIX B

SUMMARY OF LAWS CONCERNING THE CONSTRUCTION OF MERCHANT SHIPS FOR AND BY THE UNITED STATES GOVERNMENT

Sec. 701. Whenever the Commission shall find and determine, and such finding and determination shall be approved by the President of the United States, that the national policy declared in section 101 of this Act, and the objectives set forth in section 210 of this Act, cannot be fully realized within a reasonable time, in whole or in part, under the provisions of titles V and VI, the Commission is hereby authorized and directed to complete its long-range program previously adopted as hereinafter provided in this title.

Sec. 702. The Commission is authorized to have constructed in shipyards in the continental United States such new vessels as it shall determine may be required to carry out the objects of this Act, and to have old vessels reconditioned or remodeled in such yards: Provided, That if satisfactory contracts for such new construction or reconstructions, in accordance with the provisions of this Act, cannot be obtained from private the Commission is authorized to have such vessels constructed, reconditioned, or remodeled in United States navy yards. For the purposes of this section, the term "continental United States" includes the States of Alaska and Hawaii.

Sec. 703 (a). No contract for the building of a new vessel, or for the reconditioning or reconstruction of any other vessel, shall be made by the Commission with any private shipbuilder, except after due advertisement and upon sealed competitive bids.

(b) All contracts for the construction, reconditioning, or reconstruction of a vessel or vessels by a private shipbuilder under authority of this title shall be subject to all the provisions and requirements prescribed in title V of this Act with respect to contracts with a private shipbuilder for the construction of vessels under authority of that title.

(c) All bids required by the Commission for the construction, reconstruction, or reconditioning of vessels, and for the chartering of the Commission's vessels hereinafter provided for, shall be opened at the time, hour, and place stated in the advertisement for bids, and all interested persons, including representatives of the press, shall be permitted to attend, and the results of such bidding shall be publicly announced.

NOTE: The implication of these laws or provisions is that the U.S., in order to keep the fitness of a serve fleet at an operable and efficient level is that the Government build the required types and numbers of ships on its own account and charter them out to private operators under the above conditions, eliminating O.D.S. and C.D.S. All that this would require would be an appropriation by Congress. In this way the vessels would be kept in good operating condition and provide another, probably more efficient and motivated, method of subsidy application.

APPENDIX C

ASPECTS OF LABOR AND EMPLOYMENT IN THE UNITED STATES SHIPBUILDING INDUSTRY

PRIVATE SHIPBUILDING AND REPAIR EMPLOYMENT

Private Shipyard Employment - all employees (in thousands)

	Total	North Atlantic	South Atlantic	Gulf	Pacific	Other
Avg. 1963	115.5	48.1	22.7	23.0	15.0	6.6
Avg. 1964	117.1	43.9	24.0	25.9	15.0	8.4
Avg. 1965	129.7	28.9	23.6	32.7	14.4	9.8
1965						
January	127.2	47.7	24.3	27.1	16.1	10.0
February	127.8	26.9	23.9	30.7	16.1	10.2
March	127.3	48.0	23.9	29.8	15.2	10.4
April	131.1	49.0	24.0	31.9	15.9	10.3
May	130.9	49.3	23.7	32.0	15.6	10.2
June	131.9	49.8	23.3	33.2	15.7	9.9
July	115.0	38.7	23.1	34.5	9.1	9.4
August	129.4	51.4	23.4	35.4	9.8	9.4
September	132.9	52.0	23.5	35.2	12.6	9.6
October	135.0	52.0	23.8	34.9	14.7	9.6
November	133.3	51.5	23.3	33.8	15.3	9.4
December	134.3	50.6	23.3	33.9	17.2	9.3
1966						
January	142.3	54.2	23.6	35.0	19.8	9.7
February	145.1	55.4	23.0	35.4	21.4	9.9
March	145.1	55.7	22.9	35.2	21.5	9.8
April	143.7	55.4	23.0	34.9	20.9	9.5

NAVAL SHIPYARDS' EMPLOYMENT

Collective work force of 11 government naval shipyards reached a low point in February 1965.

Tabulation reveals that total employment at Portsmouth, Boston, New York and Philadelphia has steadied through April but the totals will not reflect the closing of the New York Naval Shipyard until July. Norfolk and Charleston yards' work force increased by 2,500 and 2,100 gain was registered within Puget Sound, Mare Island, San Francisco, Los Angeles and Pearl Harbor yards' grouping since February 1965.

Naval Shipyard Employment - All Employees (In Thousands)

	Total	Boston New York Portsmouth Philadelphia	Norfolk Charleston	Puget Sound Mare Island Los Angeles Pearl Harbor San Francisco
Avg. 1959	96.7	39.8	18.7	38.2
Avg. 1960	96.0	40.3	18.3	37.4
Avg. 1961	98.4	41.4	18.2	38.8
Avg. 1962	98.5	40.5	18.1	39.2
Avg. 1963	93.9	38.7	12.5	37.7
Avg. 1964	87.4	33.8	16.8	36.7
Avg. 1965	83.8	28.9	17.4	37.5
1965				
January	83.2	30.3	16.4	36.5
February	82.8	29.7	16.4	36.7
March	82.9	29.2	16.8	36.9
April	83.2	29.2	16.9	37.1
May	83.5	29.2	17.1	37.2
June	83.9	29.3	17.3	37.3
July	84.8	29.1	17.6	38.1
August	85.6	29.1	17.5	39.0
September	84.4	28.7	17.6	38.1
October	84.2	28.3	18.3	37.6
November	84.4	28.1	18.4	37.9
December	82.9	26.8	18.2	37.9
1966				
January	83.5	26.7	18.5	38.3
February	83.5	26.1	18.6	38.8
March	84.9	26.4	18.8	39.7
April	84.7	26.0	18.9	39.8

INDEXES OF STRAIGHT TIME HOURLY EARNINGS (Oct. 1951 = 100)

Selected Private Yards Engaged in Steel Vessel Construction

January	All Areas	Atlantic	Gulf	Gr. Lakes	Pacific
1956	127.4	129.9	127.3	128.6	117.8
1957	132.4	134.8	134.3	135.0	125.2
1958	128.2	139.5	142.6	144.4	133.3
1959	145.1	147.1	150.2	143.0	139.1
1960	147.4	148.7	154.7	144.6	143.1
1961	155.4	157.2	161.6	151.5	148.4
1962	159.5	161.3	164.1	158.9	153.4
1963	164.1	167.1	163.9	162.3	157.9
1964	1[illegible]0.5	174.0	168.5	164.6	162.7
1965	172.6	176.2	169.8	161.4	167.2
1966	177.2	180.1	172.0	167.1	170.1
1966					
Jan.	175.6	180.1	172.0	167.1	170.1
Feb.	175.7	180.5	171.2	167.3	170.1
Mar.	176.4	181.4	171.7	168.5	170.3
Apr.	177.1	182.3	171.9	168.8	170.3

NEW INDEX: Steel Vessel Construction - All Regions (June 1962 = 100)
Not Comparable with Oct. 1951 = 100 Index

1965					
Jan.	106.6	May	107.2	Sept.	107.2
Feb.	106.6	June	107.1	Oct.	107.4
Mar.	106.8	July	106.5	Nov.	107.9
Apr.	106.8	Aug.	107.1	Dec.	108.3
1966					
Jan.	108.5	Mar.	109.1		
Feb.	108.6	Apr.	109.5		

HOURS AND EARNINGS: Production Workers or Nonsupervisory Employees

Shipbuilding & Ship Repairing	Average Weekly Hours	Average Hourly Earnings	Average Weekly Earnings
Avg. 1963	41.0	$3.12	$127.92
Avg. 1964	40.7	3.15	128.21
Avg. 1965	40.5	3.15	127.58
Mar. 1966	41.8	3.29	137.52
Apr. 1966	41.2	3.27	134.72
May 1966	41.2	3.28*	135.14*

*Preliminary

Durable Goods	Average Weekly Hours	Average Hourly Earnings	Average Weekly Earnings
Avg. 1963	41.1	$2.63	$108.09
Avg. 1964	41.4	2.71	112.19
Avg. 1965	42.0	2.79	117.18
Apr. 1966	42.2	2.88	121.54
May 1966	42.3	2.88	121.82
June 1966	42.3	2.88	121.82

CONSUMER PRICE INDEX (Large Cities) - New Series (1957 - 59 = 100)

	1962	1963	1964	1965	1966
January	104.5	106.0	107.7	108.9	111.0
February	104.8	106.1	107.6	108.9	111.6
March	105.0	106.2	107.7	109.0	112.0
April	105.2	106.2	107.8	109.3	112.5
May	105.2	106.2	107.8	109.6	112.6
June	105.3	106.6	108.0	110.1	112.9
July	105.5	107.1	108.2	110.2	
August	105.5	107.1	108.3	110.0	
September	106.1	107.1	108.4	110.2	
October	106.0	107.2	108.5	110.4	
November	106.0	107.4	108.7	110.6	

NOTE: Consumer Price Index for June 1966, Based On 1947-49 = 100 Was 138.5, Based On 1939 = 100 Was 233.1

WHOLESALE PRICE INDEX METALS & METAL PRODUCTS (Group 10)
New Series (1957-59 = 100)

	1962	1963	1964	1965	1966
January	100.7	99.5	101.7	104.5	107.0
February	100.6	99.4	101.8	104.6	107.5
March	100.4	99.4	102.0	104.8	108.0
April	100.3	99.4	102.2	105.2	108.2
May	100.2	99.4	102.1	105.7	108.4
June	99.8	100.0	102.3	105.9	108.7*
July	99.7	100.0	102.5	105.8	
August	99.8	100.1	103.0	106.2	
September	99.7	100.3	103.0	106.2	
October	99.4	100.9	103.8	106.3	
November	99.3	101.0	104.3	106.7	
December	99.3	101.3	104.7	106.6	

*Preliminary

APPENDIX D

COMPARATIVE DATA OF WORLD SHIPBUILDING

In this Appendix data are presented on world shipbuilding activity, capital investments in shipyards, and the ratio of ship versus other machinery sales by major shipbuilding companies. It will be noted that the number of ships launched worldwide has increased linearly since 1962. The exponential growth of world trade largely supported by low unit cost transportation, which introduces many marginal goods into world trade, may result in a continuance of this trend.

It should also be noted how capital investments in modern shipyards of Japan, Sweden, and Germany have shifted from capital intensity in steel fabrication and shop equipment to an emphasis towards transportation equipment and facilities for hull assembly and ship erection.

It is similarly interesting to note that Japanese shipyards, whose sales are represented by machinery and shipbuilding percentages, have a contribution of at least 50% non-shipbuilding activities to their sales volume, which assures steady employment and utilization of facilities within the highly fluctuating shipbuilding industry.

Finally, we present a listing of the principal shipyards of the world, ranked in order of tonnage launched. It should be noted that not a single U.S. shipyard is represented among the 10 major shipyards of the world since 1961, although a similar list of world shipyards ranked by the number of employees contains at least 4 U.S. shipyards. Also, as indicated earlier, no direct conclusion can be drawn from such a comparison which certainly has some bearing on estimates of effective use of facilities and labor.

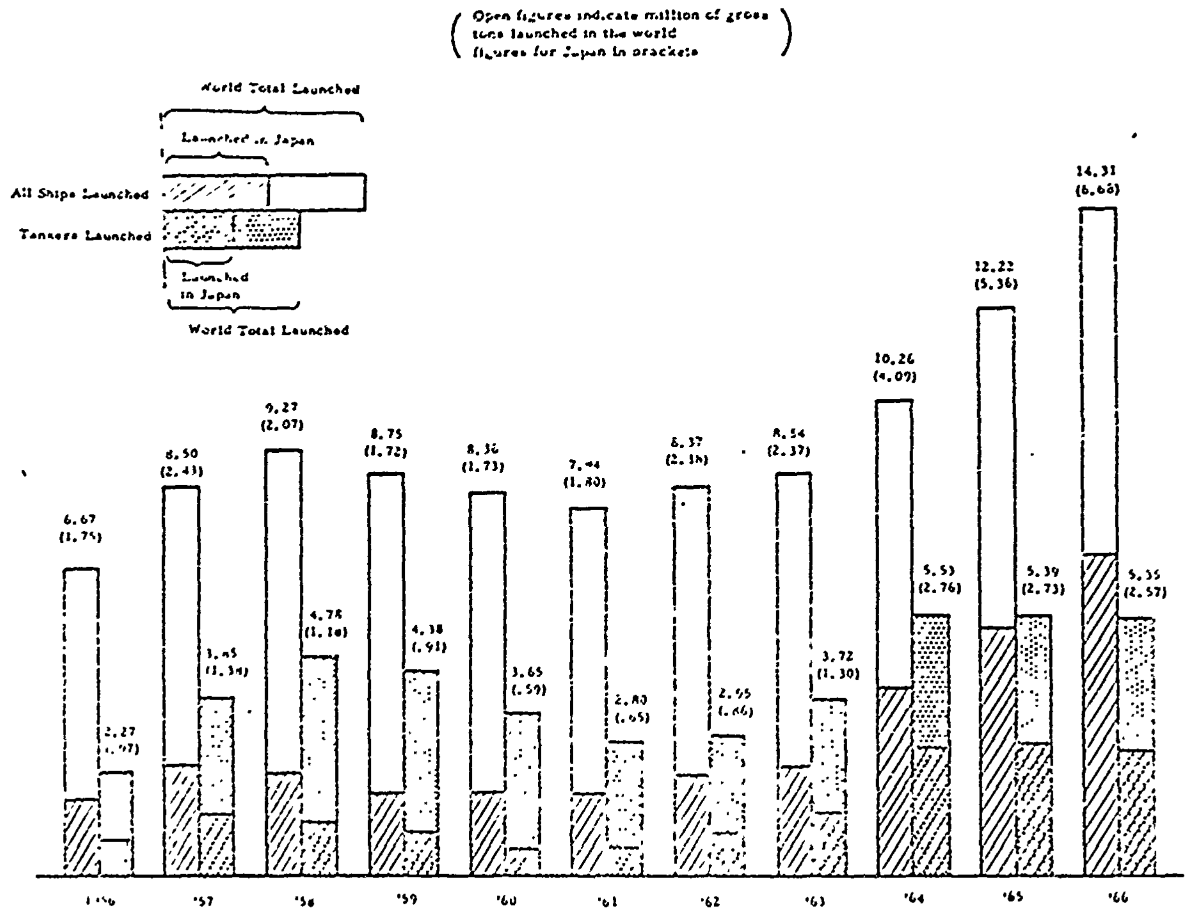
No. 2 RANKING OF PRINCIPAL SHIPYARDS IN ORDER OF TONNAGES LAUNCHED

Year / Rank	1961 Name of Shipyard	1961 Tons Gross	1962 Name of Shipyard	1962 Tons Gross	1963 Name of Shipyard	1963 Tons Gross	1964 Name of Shipyard	1964 Tons Gross	1965 Name of Shipyard	1965 Tons Gross	1966 Name of Shipyard	1966 Tons Gross
1	Mitsubishi, Nagasaki (Japan)	246,606	I.H.I. Aioi (Japan)	287,713	I.H.I. Aioi (Japan)	346,149	I.H.I. Aioi (Japan)	484,692	Mitsubishi, Nagasaki (Japan)	618,226	Mitsubishi, Nagasaki (Japan)	732,862
2	Kieler Howaldtswerke (West Germany)	189,643	Kieler Howaldtswerke (West Germany)	247,101	Mitsubishi, Nagasaki (Japan)	339,456	Mitsubishi, Nagasaki (Japan)	434,642	I.H.I. Aioi (Japan)	487,906	I.H.I. Aioi (Japan)	517,154
3	I.H.I. Aioi (Japan)	178,833	Eriksbergs, Goethenburg (Sweden)	246,569	Kieler Howaldtswerke (West Germany)	227,857	Hitachi, Innoshima (Japan)	353,500	Hitachi, Innoshima (Japan)	422,500	Hitachi, Innoshima (Japan)	444,600
4	Eriksbergs, Goethenburg (Sweden)	170,334	Kockums, Malmo (Sweden)	224,182	Uddevallavarvet, Uddevalla (Sweden)	216,859	Kure (Japan)	324,744	Goetaverken Goethenburg (Sweden)	416,407	I.H.I. Yokohama (Japan)	432,029
5	Uddevallavarvet Uddevalla (Sweden)	166,289	Mitsubishi, Nagasaki (Japan)	214,519	Kockums Malmo (Sweden)	195,266	Mitsui, Tamano (Japan)	279,820	Mitsui, Tamano (Japan)	349,310	Goetaverken Goethenburg (Sweden)	384,000
6	Kawasaki, Kobe (Japan)	145,750	Kawasaki, Kobe (Japan)	170,711	Mitsui, Tamano (Japan)	186,600	Kawasaki, Kobe (Japan)	269,295	Kure (Japan)	319,450	Kawasaki, Kobe (Japan)	379,151
7	Adriatico, Monfalcone (Italy)	143,750	L'Atlantique (France)	164,460	Eriksbergs, Goethenburg (Sweden)	177,158	Eriksbergs, Goethenburg (Sweden)	238,857	Kawasaki, Kobe (Japan)	302,530	Mitsui, Tamano (Japan)	362,851
8	Goetaverken, Goethenburg (Sweden)	135,264	Hitachi, Innoshima (Japan)	144,650	Odense (Denmark)	170,300	Kieler Howaldtswerke (West Germany)	231,691	I.H.I. Yokohama (Japan)	298,568	Nippon Kokan, Tsurumi (Japan)	356,473
9	Kockums, Malmo (Sweden)	132,403	Goetaverken Goethenburg (Sweden)	128,578	Kure (Japan)	157,416	Kockums, Malmo (Sweden)	229,600	Mitsubishi, Kobe (Japan)	267,298	Kure (Japan)	332,277
10	Brodogradiliste 3 Maj Rijeka (Yugoslavia)	101,400	Mitsubishi, Kobe (Japan)	115,240	L'Atlantique (France)	149,697	I.H.I., Tokyo (Japan)	215,383	Eriksbergs Goethenburg (Sweden)	248,347	Kieler Howaldswerke (West Germany)	321,000

(Source: Glasgow Herald Trade Review)

"Shipbuilding Industry in Japan After World War II"
by Dr. Hisashi Shinto
May 15, 1967

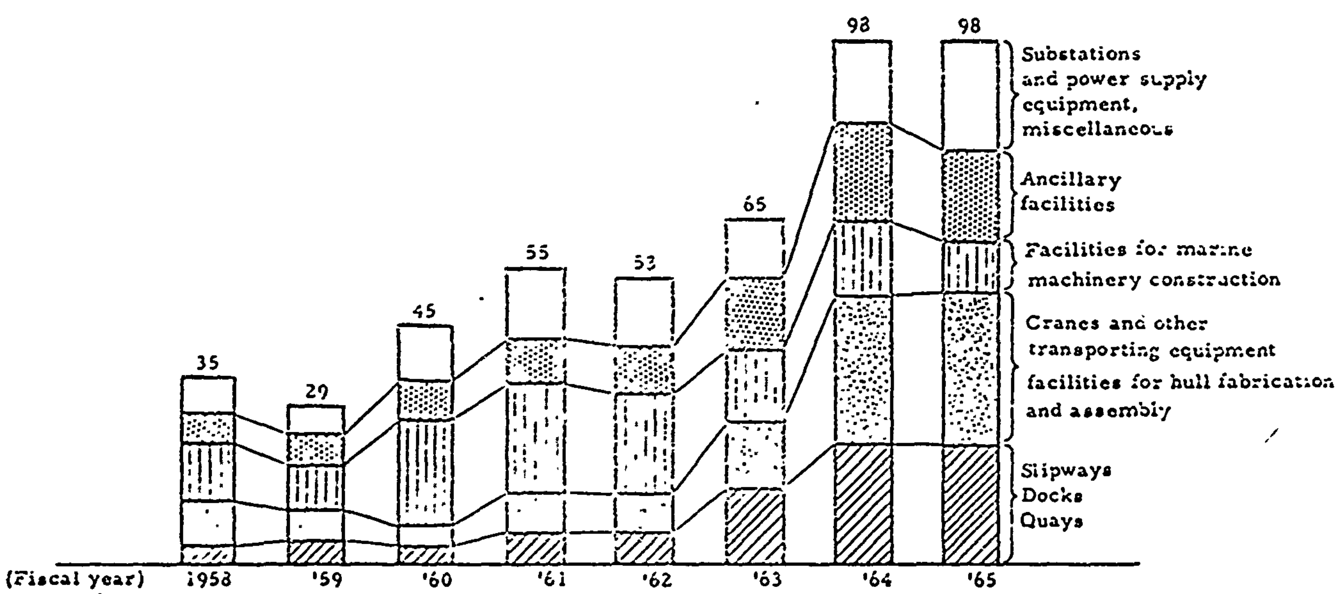
SHIPS LAUNCHED IN THE WORLD AND IN JAPAN



"Shipbuilding Industry in Japan After World War II"
by Dr. Hisashi Shinto
May 15, 1967

CAPITAL INVESTMENTS IN SHIPYARDS

(Figures indicate million U.S. $)



Source: Ministry of Transportation

"Shipbuilding Industry in Japan After World War II"
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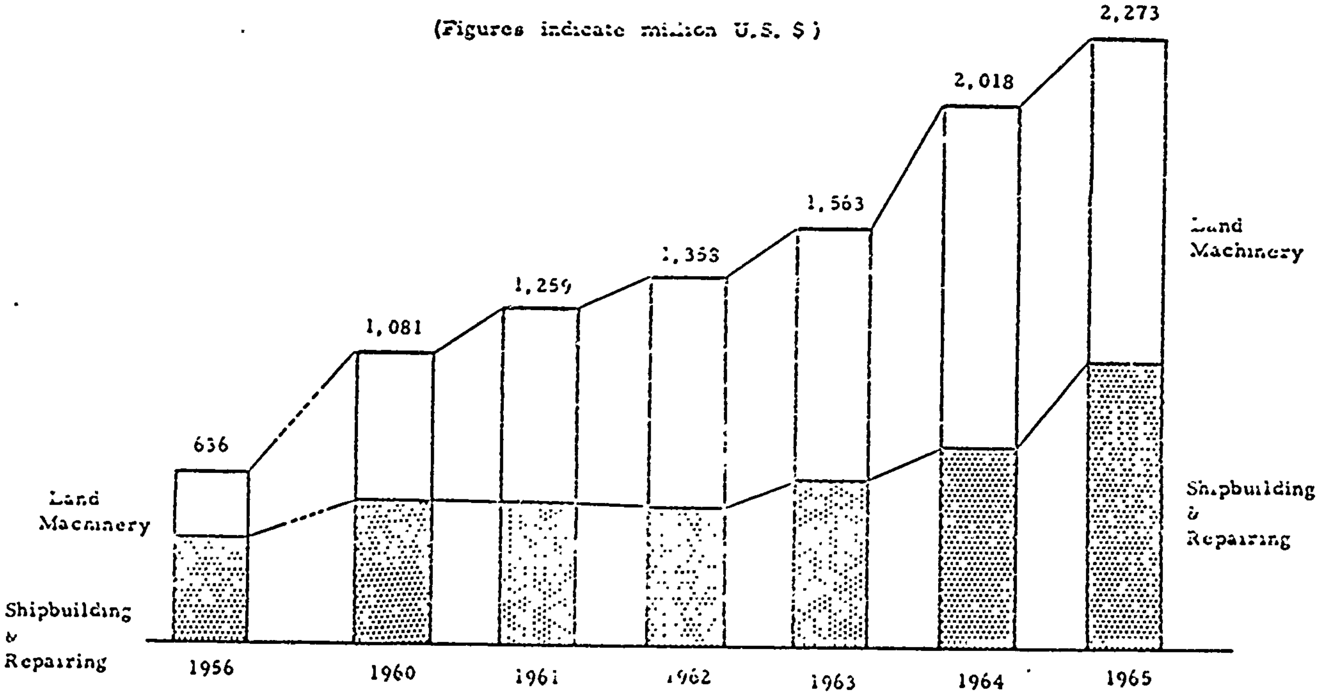
SALES VOLUME OF MAJOR SHIPBUILDING COMPANIES



"Shipbuilding Industry in Japan after World War II"
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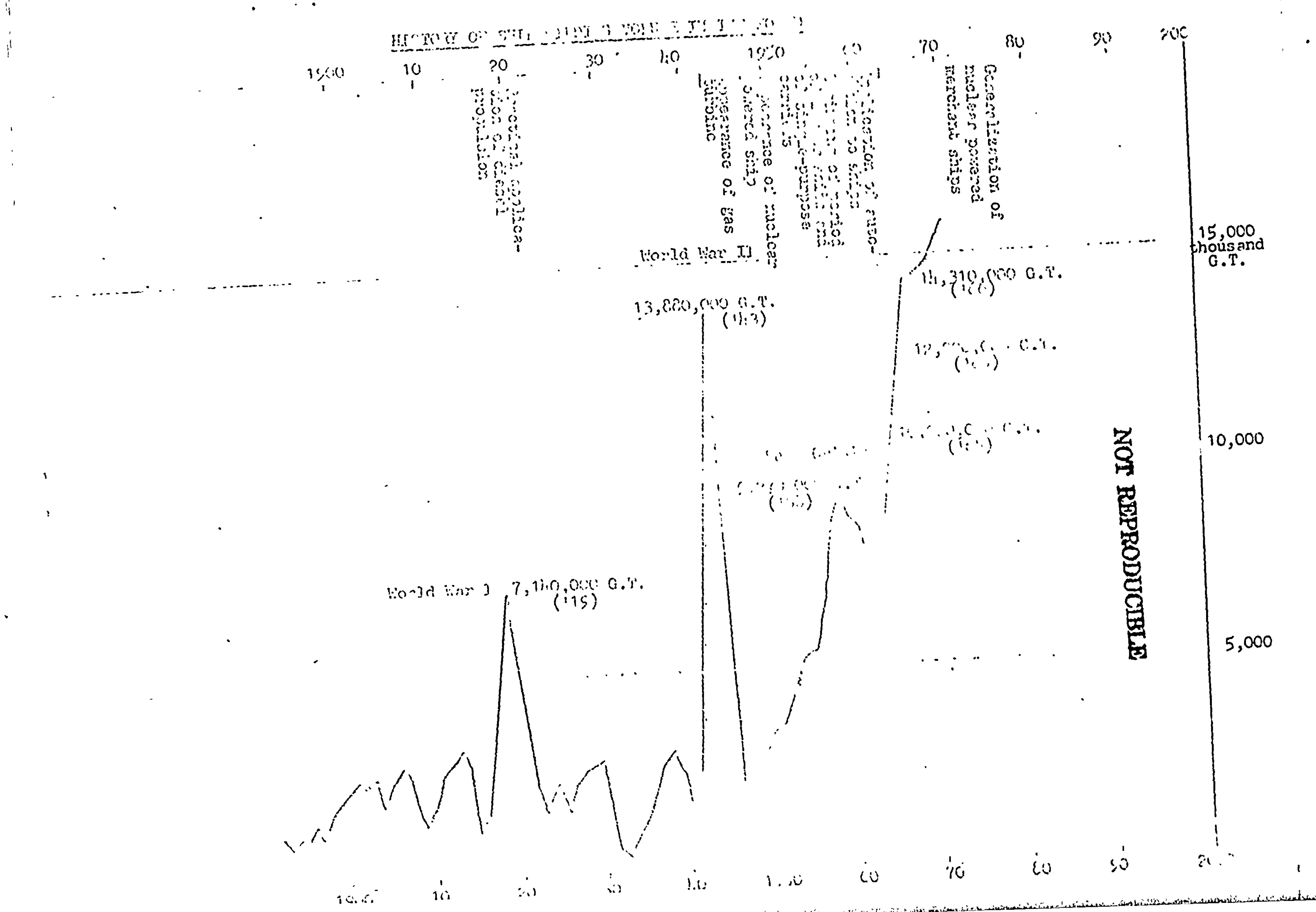
World War I
7,1[illegible],000 G.T.
('19)
World War II
13,880,000 G.T.
('43)
Appearance of gas turbine
Generalization of nuclear powered merchant ships
15,000 thousand G.T.
10,000
5,000
1900
10
20
30
40
70
80
90
200

APPENDIX E

FOREIGN SUBSIDIES AND SHIPBUILDING AID*

Compiled by Westinform

A SUMMARY of national aid to promote the competitiveness of shipbuilding, in both the home and export markets of the eleven principal shipbuilding countries of the world, is listed in Table 1. U.S.A. is exceptional in that State intervention is aimed solely at promoting the domestic shipbuilding and shipping industries. The remaining countries stimulate sales at home and abroad by artificially reducing costs (subsidy) or by facilitating the securing, perhaps on favorable terms, of credit by owners. France, Italy, Spain and U.S.A. provide direct subsidies to allow the prices offered by their shipyards to be comparable to those obtainable in other centres. In addition costs or prices are indirectly affected by remission of indirect taxes, special scrapping or trade-in allowances, tax reliefs and depreciation rates. Facilities for buyers have the general aim of providing funds or enabling private organisations to provide funds for building that are readily available and can be advanced to borrowers at rates comparable to those obtainable elsewhere. Though subject to limitation on total loans, rates of interest and repayment period, the effects of these facilities tend to even out on the world scale. Only in the U.S.A. and U.K. do they appear to favor the domestic owner, and only in the U.K. do they represent the only form of aid for the shipbuilder.

* Ref. International Marine Design and Equipment, 1965

In the shipbuilding export market, business centres on bulk carrier construction for the oil-tanker and dry-cargo trades. Ownership of these vessels is distributed in a wav not directly related to the output of domestic yards. For example, at 1st January, 1964, a third of tanker tonnage was under Greek, Liberian or Norwegian flags, though Greece and Liberia are not major shipbuilding countries and Norway is only eighth on the world list. Japan's position as leading shipbuilder and ship exporter is not matched by the size of her own fleet, though this is growing at a rate exceeding that of any other country excluding only Russia. Japan is unique in that her domestic market requires no subsidy because prices there form the ideal on which subsidies in other countries are generally based.

If we regard subsidies as essentially a means of propping up the domestic market, they mav be regarded as successful in so far as they have maintained the proportion of world construction carried out in the subsidised countries. They are an obvious and effective inducement to buy at home, especially in countries with moderate-sized fleets whose shipbuilding costs and output are per se uncompetitive. Indirect subsidies are of greatest value where they reduce costs internally by encouraging investment and the renewal or replacement of shipbuilding machinery and equipment - as in Sweden.

The British shipbuilding industry is not subsidised, though the domestic market was selectively encouraged by the 1963 Credit Scheme, and hitherto there has been little justification for special measures to expand the British fleet. For international trading, however, there is a progressive demand for the larger bulk carriers and oil-tankers on which the freight-rate structure will soon rest. These ships represent the major element of the shipbuilding export markets of the world, and current prices are determined by the factor of high output for a mass market, as exhibited by Japan. Production of ships in this class for Britain's domestic market may be adequate to allow throughput, allied to improved production techniques, to reduce prices: but in the interests of British shipbuilders and to further reduce costs, the export market must be encouraged.

In most countries where the machinery of credit is lubricated by government intervention, the sources and supervision of credit are centralized in one organisation to which foreign owners or their builders can apply. Owners seeking credit facilities in the United Kingdom, however, are obliged to seek funds in every side street of the City, addressing themselves to as many bankers as their language or patience will allow. They are more often unable to borrow than unwilling to buy. In Japan most of the money required to drive a large ship through the yards is provided by a government export credit corporation nearly half of thefunds available to which is devoted to shipbuilding. Can Britain not have credit counter for shipowners here in London?

TABLE I

FRANCE

Subsidy: Maximum of 16.75% of cost for ships above 3,000 g.t. restricted to 7 yards.

Credit Facilities: interest above 4.5% for construction for French owners in French yards paid by Government at their discretion.

Export Credit: Government-sponsored loans guaranteed up to 70% for 6 years.

Tax Relief: on construction and depreciation (12-5% for 8 years or 31.5% digressively to write-off in 6 years).

ITALY

Subsidy: average of 22% of construction cost, including subsidy of propulsion unit. In addition 35,000 lire per ton of scrapped vessel up to 75% of tonnage scrapped.

Credit Facilities: 50% of cost of 15 years, Government paying 3.5% of interest. State-owned yards allow deferred payments up to 10 years.

Tax Relief: all provisions exempt from customs duties and taxes.

SPAIN

Subsidy: 9% of cost of propulsion machinery, if Spanish built; 6% if foreign-built. Bonus of 4-6% to yards for ships built for Spanish owners. Taxes imported ships, derates exported ships.

Indirect Aid: 80% of credit at 4% for 10-20 years, contingent upon scrapping of old vessels.

Export Credit: 6-6.5%, debt compulsorily insured. Ships exported attract a refund of 9% of indirect taxes paid previously.

USA

Subsidies: up to maximum of 55% of cost.

Credits: reduced interest rates for period up to 20 years.

Insurance: of loans up to 75% of cost for (a) construction and no. of mortgages up to 87-1/2% of cost; premiums of 1/4-1/2% on (a) and 1/2-1% on (b).

Mortgage: mortgage purchase of ships from the Government at 12-1/2% down, remainder during life of vessels at 3-1/2% per annum.

Trade-in Allowance: For U.S.-owned vessels against purchase of new vessel.

JAPAN

Export Credit: 56% of contract price to yards at 4-7% per annum, repayment deferred after delivery and made over period of 8 years +24% at 9-10%. Average 5.5-6%. Terms to shipowner 80% over 8 years; 1% insurance on loan paid by Government.

Domestic Credit: Government loans, private bank loans, scrap and build incentives.

U.K.

Domestic Credit: Temporary credit programme. £75m. for loans up to 80% contract price, repayment in 10 years at prevailing Government lending rate of 4-1/2 - 5-1/8%.

Export Credit: Government insurance, guarantee or underwriting of loans made by private financial institutions or banks. Premiums paid by builder calculated on a commercial basis.

WEST GERMANY

Export Credit: 5% interest (maximum), repayable over 10 years.

Tax Incentive: partial compensation, amounting to 7% is granted for the tax on the sale of materials manufactured in Germany (West) and used in ships built for export.

SWEDEN

Domestic Credit: Government guarantee of credits to shipyards.

Export Credits: Issue of bonds by Government-sponsored company to refinance export credits.

Fiscal Incentives: shipyards entitled to write-off 20% paid value or 30% book value engines and equipment. An amount equal to 40% of taxable profits may be transferred free of tax to an investment reserve fund and this accumulated reserve may, provided the Government gives its permission in each case, be used for tax-free depreciation of newly acquired facilities. Stores and materials may be entered on the account at 40% of their actual market value.

NETHERLANDS, NORWAY, DENMARK

The governments of these countries appear to participate to a lesser degree all round in rendering aid to their domestic shipbuilding industry. The aid is primarily in the form of credit facilities -- usually quasi-Government, quasi-private.

TABLE 2

Relative Output Performance in the Export Market of the Four Main Credit Facility Countries in the Latest Seven Year Launching Cycle: 1955-1962 and 1962-1963. Percentage of total exports of the world is shown in parentheses. (Gross tons)

YEAR	WORLD (100%)	JAPAN (% of Total)	U. K. (% of Total)	GERMANY (WEST) (% of Total)	SWEDEN (% of Total)
1955	2,289.781	583,146 (25.4)	539,336 (23.5)	403,292 (17.6)	362,708 (15.8)
1956	3,199,740	1,241,820 (38.8)	434,562 (13.6)	621,431 (19.4)	323,339 (10.1)
1957	3,885,913	1,512,624 (38.9)	261,392 (6.7)	778,357 (20.0)	436,677 (11.2)
1958	4,483,990	1,256,593 (28.0)	337,868 (7.5)	860,262 (19.2)	469,355 (10.4)
1959	3,866,988	997,640 (25.8)	115,452 (3.0)	845,992 (21.9)	549,171 (14.2)
1960	3,347,354	923,766 (27.6)	145,895 (4.3)	784,498 (23.4)	456,409 (13.6)
1961	3,178,114	747,818 (23.5)	280,733 (3.7)	541,985 (17.0)	479,403 (15.1)
1962	3,456,499	876,794 (25.4)	164,892 (4.8)	683,881 (19.8)	596,618 (17.3)
1963	4,344,831	1,496,759 (34.4)	283,654 (6.5)	644,012 (14.8)	698,341 (16.1)

TABLE 3.

Fleets of Four Credit Facility Countries 1955-1963 (Gross tons)

YEAR	WORLD		JAPAN		U. K.		GERMANY (WEST)		SWEDEN	
1955	32,492	100,568,779	1,770	3,735,318	5,632	19,356,660	1,885	2,644,130	1,217	2,807,166
1956	33,052	105,2[illegible],361	1,891	4,075,781	5,508	19,545,875	2,077	3,197,773	1,223	2,922,092
1957	33,804	110,246,081	2,032	4,415,070	5,427	19,857,491	2,314	3,597,079	1,205	3,047,535
1958	35,202	118,033,731	2,413	5,465,442	5,417	20,285,776	2,367	4,055,853	1,218	3,303,078
1959	36,221	124,935,470	2,775	6,276,689	5,395	20,756.535	2,460	4,439,590	1,210	3,523,423
1960	36,311	129,769,5[illegible]	3,124	6,931,436	5,246	21,130,874	2,449	4,536,591	1,211	3,746,866
1961	37,792	135,915,956	3,733	7,953,984	5,182	21,464,522	2,454	4,771,080	1,243	3,996.335
1962	38,661	[illegible]	4,372	8,870,155	5,000	21,658,142	2,492	4,923,846	1,233	4,166,783
1963	39,571	145,8[illegible]	4,819	9,976,668	4,751	21,565,150	2,481	5,05[illegible],250	1,208	4,176,326
	Increase+ or decrease - 1955 to 1963									
1955 to 1963	+21.8%	+45.0%	+172.2%	+167.0%	-15.6%	+11.4%	+31.6%	+91.0%	-0.7%	+48.8%

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13. ABSTRACT

It is the purpose of this study to discuss some of the requirements for increased ship manufacturing productivity. In order to accomplish improvements, an integrated effort must be made to utilize the multitude of modern production, material handling, control, management, and labor effectiveness methods. Only if and when ship production is transformed into a well balanced and planned production process will substantial improvement occur.